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Pasteurisation..

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PASTEURISATION

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BY

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"Ollett" Gold Medallist, 1932

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PREFACE TO THE SECOND EDITION

FOUR years have elapsed since this volume first appeared, and that period has witnessed a steady development in the pasteurisation of milk and in other forms of heat treatment. That these processes are likely to become more important to the life of the community in the near future is evidenced by the powers already conferred upon the Minister of Food regarding heat-treatment and by the proposals now put forward for this process to become compulsory for all milk other than that produced from tuberculin-tested cows. These powers should certainly become operative at an early date in order to give full protection to the milk-consuming public.

No apology is made for the stress which has been laid upon the need for efficiency, particularly with regard to the high-temperature, short-time process which, in this volume, has received the increased consideration to which it is entitled. In some quarters, too much inefficient treatment has provided a basis for doubts regarding the advantages to be derived from the process. No purveyor of food can afford to produce an article regarding which doubts may arise and for this reason it is hoped that both plant operators and supervisory officials will derive some useful information from the succeeding pages which will assist in the production of an article that is above suspicion. If this result is achieved and a better understanding regarding the technique of milk processing ensues, the author will feel amply repaid.

H. H.

May, 1947.

PREFACE

For many years, all suggestions that milk should receive any form of heat treatment have been strenuously denounced by otherwise well-informed persons. Pasteurisation in particular has borne the brunt of considerable criticism which has not detracted in the slightest from its usefulness as a means of guaranteeing the safety of the country's milk supplies. All foodstuffs should, of necessity, be free from disease-producing organisms, milk being no exception in this respect, and it is only by the application of efficient methods of treatment that safety can be guaranteed.

All methods of pasteurisation carried out in this country are not satisfactory, and this lack of efficiency has provided the critics with their most weighty arguments against the process. No one can deny, least of all those whose criticism is so widely advertised, that the process will, if properly understood and efficiently carried out, guarantee a safe article for human consumption, which is a factor of paramount importance.

The author's aim has been to answer all critical statements by emphasising the need for efficient pasteurisation of all milk for the general well-being of the community at large, and in this he hopes that he has succeeded. A thorough understanding of the methods employed is vitally necessary not only for the public health administrator but also for the plant operator, and detailed attention has been given to these matters. The essentials of efficient operation and control of processing plants must, of course, be thoroughly understood. These have received special emphasis. This volume attempts to place before all interested parties the necessity for processing, the methods necessary to ensure that all milk is rendered safe, and the control measures required to attain this desirable state of affairs. If this end can be achieved generally and the public supplied with a safe, guaranteed milk, to their general benefit, then the author will feel that his efforts have been amply repaid.

HARRY HILL.

Town Hall,
Palmer's Green, N. 13.
March, 1943.

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PASTEURISATION

CHAPTER I

INTRODUCTORY

THE public health problems connected with milk supply and particularly with regard to supplies for large centres of population, have become matters of fundamental importance and continue to engage the serious attention of public health authorities in every civilised country. Public opinion is beginning to object to any lack of hygienic precautions in the distribution of milk intended for human consumption and is demanding that its quality should be constantly improved. In other words, the consumer is rapidly becoming aware of the fact that milk should be rich in nutritive constituents and, in addition, should be free from any organisms which may be harmful to health.

The laboratory worker has demonstrated that milk is frequently the responsible agent for the transmission of infectious diseases, and it is generally known that typhoid and paratyphoid fevers, diphtheria, scarlet fever, tuberculosis and undulant fever, together with other less common infectious diseases and human ailments, are easily propagated by means of milk.

There are innumerable ways in which the liquid may become contaminated and unsafe from the hygienic standpoint. Probably the chief of these is the fact that milk is normally handled many times between the time of its production and its delivery to the consumer. Further, there is difficulty in ensuring that each separate handling is carried out with all the precautions prescribed by modern hygienic requirements, while it must be remembered that any single operation, if improperly executed, may completely nullify the effect of others.

Milk, as the medical profession has repeatedly pointed out to the public, is a good and indispensable food, which is used daily by the majority of families to whom, when produced and distributed under hygienic conditions, it brings health and strength. Unfortunately, if such requirements are not observed, it may be the cause of disease and death. It is the staple food of old people and invalids; it brings vitality to children and should consequently contribute to the sound development of future healthy generations. Again unfortunately, it may be the means of destroying children's health, thereby depriving society of factors which are most essential to its progress, and the public have been left to learn by bitter experience of disease and epidemics that raw milk, as produced at the present time, may be unsafe for their consumption. The vital importance of milk is leading public opinion to insist on the adoption of suitable control measures by the licensing authorities concerned, and it is the duty of such bodies to allay any doubts regarding the efficacy of our public health system by providing them with a clean and safe milk supply. It is extremely humiliating to realise that members of the United States Army when in this country were forbidden to drink milk unless supplied from tubercle-free herds *and* pasteurised in addition. Milk in its natural state was regarded by the United States authorities as highly dangerous to health.

At the present time, it is impossible to guarantee the safety of milk as produced. One result has been to cause the responsible authorities to strive by every possible means to obtain a product for human consumption as safe as humanly possible. This endeavour has resulted in a spate of legislation in order that the liquid should correspond more closely with scientific discovery and satisfy the essential requirements of public health. As a result, continued progress has been achieved in the production of milks treated by heat to give them added safety, the process generally adopted for this purpose being pasteurisation. It must be apparent that pasteurisation has come to stay whether one agrees with such treatment or not. Particularly is this so when one considers the powers vested in the Minister of Food under Regulation 55G of the Defence (General) Regulations, 1939 to make Orders specifying the grades of milk which may be sold in any particular district, pasteurised milk being one of these.

Louis Pasteur, the great French scientist, first explained the benefits to be derived from the application of heat to certain foodstuffs, although he was not primarily responsible for demonstrating the value of such methods. That distinction falls to an Italian biologist Lazzaro Spallanzani, who, in 1768, conserved food by means of heat. The employment of this method of food preservation was also investigated by the Swedish chemist, Carl

Wilhelm Scheele in 1782, while in 1795, Nicholas Appert, the inventor of canning, applied his process to milk, this contribution to scientific knowledge resulting in the award of 12,000 francs by Napoleon.

Although these scientists forestalled Pasteur in the application of heat as a means of food preservation, it is to him that posterity owes the present process of pasteurisation. Pasteur was interested in the organisms present in milk; during the early part of his career he paid considerable attention to the problem of bacterial growth in that liquid. Between 1857 and 1862, he proved that milk became sour owing to the multiplication of organisms which he believed obtained entrance from the atmosphere. He demonstrated that heating milk would destroy many of the organisms present and thus postpone souring, and his report on this subject was presented before the Scientific Society at Lille in August, 1857.

Between the years 1860 and 1864, Pasteur was also engaged in investigating the causes of wine spoilage and he demonstrated that a temperature of between 122° to 140° F., when applied for a few minutes, would preserve the product from abnormal fermentations and souring. During the period when he was undertaking his research work on milk, a milk product, preserved by heat, was placed on the market in America. In 1856, Gail Borden obtained patent rights for a method of concentrating milk under a vacuum, his work following on the lines of research undertaken by Pasteur.

In spite of the discoveries of Pasteur and Borden, twenty years elapsed before the value of heat as a means of safeguarding the milk supply was realised. The first commercial pasteuriser was manufactured in Germany during 1880 by Ashborn, of Hildeshein, while about the same time, Fresca, of Berlin, produced a similar plant. A few years later, a Danish pasteuriser appeared and, by 1885, milk was regularly pasteurised in Copenhagen and Stockholm, not primarily for public health reasons but from a commercial viewpoint.

In 1886, the German chemist, Franz von Soxhlet, advanced matters a step further by advocating the sterilisation of all milk used for infant feeding. He stated that infants fed on such milk possessed a greater chance of survival and, far in advance of his time, he invented a method of sterilising milk in bottles, which be patented. His methods were investigated by Caillé and Jacobi in New York during the years 1888–89, and they urged that similar methods should be employed in America.

Pasteurisation, in its early stages, was prompted by commercial considerations and a number of different types of apparatus were devised with a view to maintaining the keeping qualities of large volumes of milk as cheaply as possible. The inventors aimed at reducing any spoilage likely to occur when supplies had to be transported from far afield, for it was obvious that there were considerable advantages to be derived from being able to lengthen the life of such milk. Volume of output, therefore, became much more important than efficiency, always provided the life of the milk was preserved, and "continuous flow" apparatus was considered to be the most desirable type of plant. Public health research workers had, by now, turned their attention to milk and had discovered that organisms of animal diseases, such as tuberculosis, could be carried by the liquid to the detriment of the consumer. They also discovered that these organisms could be destroyed by the pasteurisation process, always provided that time and temperature were correct and that a given quantity of milk was treated at any one time. These investigators specified suitable temperatures and periods of heating, but their ideas were naturally unpopular with people supplying milk whose chief interest lay in the volume which could be handled as cheaply as possible, and the apparatus then manufactured was chiefly designed to attain that end.

The method of holding heated milk in tanks for a period of 30 minutes was first tried experimentally in 1895 by Monrad in Copenhagen, and as the results obtained were an improvement on the "Flash" method then universally employed, its adoption was suggested to all health authorities. Little success in these efforts was achieved, and it was not until 1907 that Dr. Charles E. North, in New York, installed the first large-scale low-temperature plant. This method of heat treatment rapidly developed in the United States of America, but it was not until 1922 that any official action to control milk treatment in this country was taken by the Minister of Health. In that year the term "pasteurisation" was given a definite legal meaning by the Milk and Dairies (Amendment) Act, while later, in the same year, the first Milk (Special Designations) Order became operative, to be rapidly superseded in 1923 by another Order which remained in force until 1936.

During the years which have followed, public health pioneers had to struggle against prejudiced opponents of the process. Compared with other scientific developments, the pasteurisation process always appears to have offered ample material for controversy, so much so that the layman may well have given up hope of ascertaining the true position. For all practical purposes, however, the question may be taken as settled, by far the largest body of knowledgeable opinion being definitely in favour of the process, although it must be admitted there is a strong and vociferous minority who are against the application of any form of heat treatment to milk. Such criticism cannot be attributed entirely to vested interests or even to mere ignorance; if this were so, little notice need be taken of it. It seems that there is a body of unprejudiced, responsible people proclaiming in perfectly good faith that pasteurisation is undesirable for a variety of reasons and does more harm than good. Confusion has been caused by statements made by this body of otherwise well-meaning persons and these fallacies can only be dissipated by considering the objects which satisfactory processing must achieve.

Before doing so, it is necessary to outline briefly the methods by which milk may be treated by heat. These are as follows:—

(1) *Pasteurisation.* The most popular system of processing milk by heat, several methods being employed for this purpose, of which the high- and low-temperature processes and pasteurisation-in-bottle are the only ones legally recognised.

(2) *Stassanisation.* A Continental process as yet hardly out of the experimental stage, particularly in this country, and one which is another form of high-temperature, short-time treatment for which it claims to be an efficient substitute.

(3) *Sterilisation.* A process by which milk is heated sufficiently to destroy practically all bacteria which it may contain.

(4) *Homogenisation.* A certain proportion of milk is treated in this manner prior to pasteurisation and always before it is submitted to the sterilisation process. The aim of this treatment is to emulsify the fat globules so as to ensure an equal cream content throughout the liquid.

Whichever process is chosen, careful attention must be paid to the following points:—

(*a*) How far is the process efficient in attaining its object?
(*b*) Is the process detrimental to the food value of milk?
(*c*) Does processing increase the retail price of the product?

An efficient pasteurisation process must satisfy three different requirements. Milk must be treated hygienically, it must be rendered safe for human consumption, and the nutritional value must not be impaired. It would seem, perhaps, that too much is expected of the process, but it must be emphasised that if up to date equipment, designed according to modern requirements and suitably installed and operated, is employed, these requirements can be adequately met.

Milk contains a large amount of protein in a colloidal state and is an extremely favourable liquid for bacterial development. In addition to acidifying organisms, it also contains proteolytic, peptonising and putrefying bacteria. Owing to the rapidity with which acidifying organisms develop under favourable circumstances, the action of the other bacteria in milk is somewhat curbed. If the acidifying organisms were entirely destroyed, those which remain would cause the milk to putrefy instead of sour. Such putrefaction is not unknown, particularly following a too speedy or excessive application of heat.

The ideal method of treatment is one which does not completely destroy the lactic acid organisms but merely inhibits their growth and vitality, a sufficient number remaining in milk to prevent the liquid's putrefaction by the other bacteria present. This retardation of souring has probably caused critics of the system to state that pasteurisation is practised in order that the keeping quality of milk may be prolonged. This accusation might have been true in the early stages of development as already mentioned, but cannot be said to apply at the present time. Public health authorities are demanding that the consumer should be protected from *all* disease producing organisms which may be present and this request has been ably answered by the more enlightened members of the distributive trade. The demand for safety is being insistently made by all persons interested in public welfare who refuse to be deterred by allegations that the nutritive value of milk is radically altered by the application of heat at pasteurising temperatures. Experiments have proved that the nutritive value of such milk is almost equal to that of the raw variety with the additional guarantee of safety.

Though the conditions regarded as indispensable to efficient pasteurisation can be satisfied, it does not mean that this is so in every case. Pasteurisation is primarily an industrial process depending for its success upon the sound employment of special equipment and the constant recognition of certain well-defined rules. Equipment does exist which can definitely and satisfactorily fulfil all conditions expected of the process. Therefore, no technical difficulties prevent the attainment of this aim. The fact that every type of plant cannot fulfil these conditions is not in itself a logical ground for opposing its wider application.

Innumerable statements have been made for and against this method of treatment and the process will doubtless continue to evoke either serious criticism or lavish praise from all interested parties for some considerable time to come. It cannot be denied that a large quantity of milk produced in this country is treated by heat in various ways. Enquiries will show that opinions as to the merits or demerits of pasteurisation vary according to the individual whose views are sought. It is the present consensus of the highest medical opinion that such treatment, if efficiently carried out, provides a desirable and essential safeguard, applicable to milk at relatively small cost without materially affecting the food value of the product; therefore, if such opinion were sought, the answer would be that some form of heat treatment was essential to render milk safe. Indeed, at the Annual Meeting of the British Medical Association held in 1945, the following resolution was agreed to:

> "That the council is instructed to insist that the Ministry of Health and the Ministry of Food shall secure legislation immediately requiring all milk for human consumption to be pasteurised."

Public health authorities and also many members of the distributive trade would agree with the expressed opinion of the profession. When careful consideration is given to the public health viewpoint, it is amazing that while for the last eighty years the process of pasteurisation has been available for the purpose of rendering milk safe, it would appear that its general introduction has been awaiting the emergence of public opinion in its favour. It is essential that a definite lead should be given in order to forestall any public criticism regarding the failure of those responsible to protect milk consumers from disease or even worse.

A large number of milk producers and distributors, however, appear to be against either pasteurisation or any other form of heat treatment, arguing that such processes are detrimental to the consumer's health, inasmuch as the food value of milk is impaired by heating, whatever temperature is employed. No doubt it is obvious to all concerned with the production of milk that, without some form of heat treatment, large quantities of milk now produced annually could not be sold, especially when consideration is given to the long distances which it may have to travel before reaching the consumer. In such instances, if pasteurisation in one of its various forms were not applied, large quantities of such milk would sour before delivery.

Everyone will agree that milk should always be produced in a pure, hygienic condition, but the solution of this problem is far from being achieved. Suggestions, plans and schemes for dealing with this matter are either in force or have been mooted, but one cannot pretend to ignore the difficulties experienced in obtaining milk which is safe when produced. However great the care taken, however scrupulous producers or distributors may be, there will always occur cases of involuntary negligence, accidents and defects of the human machine, which even the most stringent precautions at the point of production will never entirely eliminate. Pasteurisation is a practical process which does not "improve" milk but simply renders it safe. It must be remembered that the process should not be employed to provide an excuse for any failure to observe hygienic precautions at the source, nor for laxity on the part of producers, since unhygienic milk may, after treatment, become unfit for general distribution.

Differences of opinion as to the value of processing milk are always likely to be present in any community, but there is little doubt that pasteurisation has come to be recognised as a means of affording valuable assistance in securing a disease-free milk supply at least for some time to come. Therefore, in order to silence much of the criticism now voiced abroad, every person dealing with this process should have a sound knowledge of the principles and technique involved. In no other way can satisfaction be guaranteed or criticism nullified.

CHAPTER II

NECESSITY FOR PASTEURISATION

THE pasteurisation of milk has been practised for many years and there is little doubt that this method of processing is likely to become more widely demanded. As with all scientific discoveries, its advantages and disadvantages have been debated on innumerable occasions, often in an exceptionally heated manner. It must be admitted there is, without any doubt, considerable divergence of opinion even between the various sections of the milk industry. Although the process has received consistent ridicule in certain quarters, it must again be emphasised that its employment for the treatment of all raw milk supplies is essential and should be no longer delayed. This may appear to be a rather sweeping statement, and it is therefore necessary to consider the reasons why compulsion is so urgently and generally required.

In considering this process, there are two aspects to be borne in mind. These are the commercial *and* the public health points of view. The existence of such separate and not always reciprocal interests has somewhat confused the issue, but it should be definitely understood that the final desideratum is a *safe* milk supply for the entire milk-consuming population of this country.

Commercially, pasteurisation embodies the following conditions. Primarily, the price of the finished article should not be raised above the purchasing power of the poorest consumer. The cream-line must not be affected to any great extent, since milk possessing a deep cream-line is more favourably received by the majority of customers than is milk in which it is absent. Finally, the appearance and taste of the milk should not be altered. Consideration must also be given to the fact that an enormous quantity of milk is distributed in the large centres of population which must necessarily travel long distances before it reaches the consumer. In such circumstances some form of heat treatment is essential for its preservation. It is quite safe to say that pasteurisation has been the means of enabling quite a large proportion of the milk produced annually to reach the consumer in a saleable condition. In confirmation of this, Sir George Newman, when Chief Medical Officer of the Ministry of Health, stated :

"It is generally recognised that milk obtained from perfectly healthy cows, under the cleanest conditions, cooled immediately and distributed with the least possible handling and delay, is the best that can be procured. The difficulty in existing circumstances, however, of securing such ideal conditions for milk production inevitably restricts its supply. In a highly urbanised country such as England, transport and distribution complicate the problem of a satisfactory milk supply and in order that an adequate, safe, and cheap supply of milk should be readily available for every one, it is necessary to have to recourse to pasteurisation, which has already proved so valuable in the milk supply for cities in the United States of America."

All foodstuffs should be as fresh as possible when consumed but, owing to circumstances which often exist in the larger urban areas, it is necessary that the keeping quality of milk should be improved without altering its food value, so that it may be delivered to the public in a sweet condition. If this were not possible, a large proportion of our population would be forced to forgo this essential food, while many producers would be unable to dispose of their milk.

As Sir George Newman has stated, the ideal would be for all milk to be produced from *perfectly healthy* cows, under hygienic conditions, and for it to be consumed within the shortest possible time after production. There is likely to be greatest difficulty, however, in freeing herds from tuberculosis and in maintaining freedom from this disease, in addition to the expense attached to such eradication. Efforts to rid dairy herds of this infection have been made and subsidies have been paid to producers to encourage the attainment of this desirable state of affairs with little success. Such efforts must, of course, be continued, but the public have the right to demand that all milk should be rendered safe during the interim period which must elapse until this ideal is fulfilled. Milk of such high quality is likely, by reason of its excellence, to be always limited in quantity and, on account of its high cost, to be out of reach of the majority of the consuming population. The bulk of the milk supply does not attain such a high standard and this fact, when considered in conjunction with transport difficulties, clearly indicates the necessity for pasteurisation, not only for the sake of safety, but also to prevent losses through souring.

Efficient pasteurisation is the only method by which the distributor is enabled to *guarantee* that his milk is free from any disease-producing organisms which may be injurious to the health of his customers. To be able to give this guarantee is an asset of no little commercial value. Further, in view of recent legal decisions, the distributor must remember that should his milk be the cause of human infection, he may be liable to heavy damages by way of compensation to the affected persons. In addition, it is the only way in which he can deliver milk which will keep for a period in any way comparable to that which holds good when consumers are served with clean milk, sold fresh from the farm, immediately after production, but with the additional guarantee of safety.

Pasteurisation is not and never can be a process that will render dirty milk clean—a statement so often made in ignorance—or sour milk sweet, and it is essential that the process should only be employed for the treatment of raw milk possessing a low bacterial content. It cannot be too often emphasised that pasteurisation is not a substitute for cleanliness—*neither is cleanliness a guaranteed substitute for pasteurisation.* There is concrete evidence that cleanliness alone is not sufficient, the outbreaks of Septic Sore Throat in Brighton and district in 1929, and of Scarlet Fever at Chilgrove in 1934, clearly illustrating the point. In both these instances, the milk was produced under exceptionally clean conditions, and from all available evidence it is quite obvious that "clean milk" can never be guaranteed as "safe milk." Pasteurisation does not conceal faulty production methods. Rather does it reveal such faults, while it cannot be employed with any success to assist in the production of unclean milk.

In the foregoing paragraphs the importance of pasteurisation has been stressed from the viewpoint of various sections of the milk industry. Although one may consider that the process is a commercial necessity, this opinion cannot possibly assume the importance of the public health aspect. It is necessary, however, to again emphasise that both the milk industry and licensing authorities should be primarily concerned with the process as a means of increasing the supply of safe milk available.

From the public health point of view, the desired objects are twofold. The destruction of all organisms likely to affect the health of the consumer and which would prevent its sale in sweet condition is essential, while maintenance of the nutritive value is equally important. It is not easy to understand the apathy of the milk consumer towards the presence of disease-producing organisms in milk when that same consumer would be greatly perturbed if asked to drink water infected in this manner.

It has often been argued that if milk were produced in a cleanly manner, free from all harmful organisms, any treatment by means of heat would be unnecessary. This must be granted, but two factors prevent such a Utopian ideal being achieved, at any rate for some considerable time. There is at present no compulsion for any farmer to produce milk with a low bacterial content, free from harmful organisms, although the introduction of the Natinnal Milk Testing Scheme was a progressive move in the direction of improvements in keeping quality. Secondly, the producer is not compelled to have his animals either clinically examined or tuberculin tested at frequent intervals, although he is encouraged to do so by means of various monetary inducements. Even in the case of animals producing tuberculin-tested milk, there still appears to be some risk, always granted that this may be greatly mitigated by the supervision under which such milk is produced.

In order to realise how great is the necessity for pasteurisation, consideration must be given to certain investigations concluded some years ago. The character of ordinary supplies of raw milk from all parts of the country was investigated, before and after treatment, while Certified and Grade A (Tuberculin Tested) supplies as they were designated at that time, produced under licence from the Minister of Health, also received attention. The results of these investigations were illuminating. It was found impossible to accumulate any material quantity of raw milk on any one day in any important milk-producing area in the country which was free from tubercle bacilli. In every examination made, these organisms were present before pasteurisation, but were absent after the milk had been processed. Raw milk produced to designated standards under licence is naturally presumed to be the product of the best herds of the country. Samples of such milks examined, however, gave one positive and one doubtful tuberculous sample. This may not appear serious but, emanating as it does from herds undergoing fairly frequent veterinary inspection besides being tuberculin tested at regular intervals, it is obvious that such milks are not always what they appear to be. Further investigation showed that the bulk of the samples contained *hæmolytic* (*mastitis*) *streptococci* and *Brucella abortus.*

Statements are often made welcoming the increased production of Accredited milk as a step towards the safety of the milk supply. Such milks are clean and suitable for pasteurisation but their safety is very much in doubt. This is obvious when it is remembered that this Grade does not possess the advantage of being derived from tuberculin-tested cattle. Consideration of the aforementioned results shows that even tuberculin-tested milk cannot always be guaranteed safe in every respect. It is possible, indeed, that Accredited milk may be as heavily infected with disease-producing organisms as is ungraded raw milk. In this connection Savage has stated that the percentage of tubercular-infected samples is greater in such milk than it is in the undesignated product. In addition, the percentage of infection of tuberculin-tested milk with *Brucella abortus* is likely to be quite as high as that of ordinary raw ungraded milk, if not higher.

It has often been stated that statistics can be used, if desired, to prove any statement, but the results mentioned were obtained following examinations by experienced laboratory technicians, and can surely indicate nothing more than the serious, urgent need for pasteurisation of all raw milk supplies.

The question of disease transmission through milk must now be considered, that is infection by organisms of animal origin *and* by those from human sources. Before such consideration is given, it should be pointed out that since 1912 nearly 120 outbreaks of milk-borne epidemic diseases occurred in this country, affecting many thousands of persons.

(1) **Infection by Organisms of Animal Origin.** While human beings may not become infected by every ailment to which our cow population is subject, those diseases which may adversely affect consumers of infected milk are sufficiently formidable. Without doubt, tuberculosis is the most notable and widely known of these, but mastitis, contagious abortion, digestive infections and other minor diseases all may add their quota of ill-health.

(*a*) TUBERCULOSIS. The *Mycobacterium tuberculosis*, of bovine origin, is the commonest pathogenic organism found in milk, and, in view of the dangerous consequences likely to result from the consumption of milk so infected, it requires the most serious consideration. Bovine tuberculosis is very prevalent in these islands, its incidence increasing in our northern districts, while great variations occur between county and county, even in the same part of the country.

An exhaustive inquiry, conducted by a special Committee of the Peoples' League of Health some years ago, elicited the following facts, which have never been refuted and still hold good to-day, regarding the incidence of bovine tuberculosis in the dairy herds of this country. It was found that at least 40 per cent. of dairy cows were infected to a greater or lesser degree with the disease, the incidence of infection increasing according to the age of the animal, and there was no evidence to show any decrease in such incidence. Approximately 0·2 per cent. of dairy cows had tuberculosis of the udder and were therefore yielding milk containing living tubercle organisms although only some 3 per cent. of affected animals were actually infective at any one time. As might be expected, the proportion of raw market milk containing living tubercle bacilli varied in different parts of the country, 2 to 13 per cent. of supplies being found infected, with an average of 6·7 per cent.

The percentage of cows with infected udders was obtained by consulting records collected from different areas and it is probable that a much higher percentage would have been discovered if samples of milk from all milk-producing herds had been regularly submitted to biological examination. It has been authoritatively stated that 0·5 per cent. of milking cattle are excreting tubercle bacilli in their milk and this appears quite feasible when it is realised that the milk from animals with apparently unaffected udders may contain these organisms.

The large percentage of raw market milk infected with such organisms is due to the prevalent bulking of milk supplies. Milk from one infected cow will pollute the mixed milk from the remaining healthy animals in a herd, the extent of such infection varying according to the progress of the disease in the animal concerned, while milk from several farms will become infected if the several supplies are mixed. It is sometimes stated that bulking dilutes the infection. This fallacy has been disproved by biological examination of bulked milk supplies, infection being, in many cases, traced back to an affected animal in one particular herd. Indeed, bulked milk is usually found to be most heavily infected. The following figures set out in a report on "Tuberculous Infection of Milk" issued, in 1933, by the Department of Agriculture for Scotland illustrate that the degree of infectivity will be increased by bulking.

Certified and Grade A (T.T.) . .	1 sample out of 714 infected.
Ordinary milk in Churns . . .	10 per cent. infected.
Ordinary milk in Bulk Containers .	Over 30 per cent. infected.

The bovine type of organism is responsible for the non-pulmonary infection of man, such infection occurring almost exclusively in the alimentary tract, the predominant source of harm being infected milk consumed in its natural raw state. The disease chiefly occurs in children up to the age of five years who are the largest consumers of milk; above the age of 16 years, there is a progressive diminution in incidence. The marked fall in the non-pulmonary death rate during the last few years has been held, by many members of the agricultural community, to indicate that the disease, both in human beings and in animals, is rapidly becoming a negligible factor. This is not so, as there are several good reasons for such decrease.

For some time now greater interest has been taken in clean milk production with consequent healthier stock, together with increased veterinary inspection following which animals showing clinical signs of disease have been disposed of. More extensive sampling of milk for biological examination has been undertaken and this has caused the removal and slaughter of affected animals under the Tuberculosis Order, 1938. There has also been a considerable increase in the quantity of milk which is pasteurised prior to sale, this being very noticeable in our large centres of population. In London alone, 90 to 95 per cent. of the milk retailed is now pasteurised before distribution while in Birmingham, Glasgow and Manchester approximately 80 to 90 per cent. receives similar treatment. Child Welfare Centres have been increasingly active and many more babies are now fed on dried milk than was formerly the case. Further, such authorities who supply liquid milk are taking increasing precautions to ensure that their supplies are above suspicion. In spite of these improved measures, innumerable producers are still sending out milk which is heavily infected with tubercle bacilli.

Dr. Stanley Griffiths has reported that, in an unselected series of 1,068 cases of human tuberculosis investigated by him, 20·7 per cent. were attributable to bovine infection. His figures show an incidence of 37·55 per cent. of bovine infection in children under five years of age, with a progressive diminution to 6·25 per cent. from 16 years of age, upwards. Dr Griffiths has also shown that, in 1,321 further cases investigated, 22·47 per cent. were due to bovine infection. These figures compare favourably, or perhaps one should say unfavourably, with those mentioned in the report of the Royal Commission on Tuberculosis which stated that, of 60 cases investigated, 23 per cent. were of bovine origin.

Investigations have also revealed the fact that approximately 6 per cent. of all deaths from tuberculosis are caused by the bovine type of organism. Some 2,500 deaths occur annually from this cause, most of which are children, while at least 4,000 fresh cases due to bovine infection develop each year. The majority of these cases do not die, but the disease results in an immense amount of suffering, invalidity and other permanent deformity, together with great expense to the community in the efforts made to effect a cure. Wilson has stated that 6 per cent. of all deaths from tuberculosis aredue to infection of bovine origin and this appears to be a reasonable assumption. If this is true, as it may well be, 65,000 persons died of the disease between 1912 and 1937.

Such a deplorable state of affairs with which we are confronted in this scientific age is one which emphasises the necessity for pasteurisation. Even the Ministry of Agriculture and Fisheries recognises this process as a means of rendering milk safe from this disease, for they require, as a condition of the Attested Herds Scheme, that all milk used for the feeding of young animals in such herds must either be pasteurised or sterilised before use, if it is obtained from a non-attested source. As this treatment is considered desirable to prevent the infection of animals, how much more necessary is it to pasteurise all raw milk used for human consumption ?

(*b*) MASTITIS. Mastitis is a common disease of dairy cattle and pathological examinations of cows which have passed through several pregnancies show that many such animals have suffered to some extent. It is commonly found that only one quarter of the udder has been attacked, the disease being frequently spread by the hands of milkers. Mastitis is caused by a variety of streptococci and other organisms, the chief of which is the *Streptococcus agalacticæ*. So far as is known at present, this organism is not infective to human beings. Infected milk, however, cannot be considered suitable for human consumption owing to the large number of pus cells which it contains, while Brooks and Tiedeman have suggested that toxic substances may be present which may give rise to gastro-intestinal disturbances in susceptible human subjects.

Some 40 to 50 per cent. of dairy herds are affected to some extent and it is probable that this percentage of farms are sending out milk infected with mastitis organisms. Although the causative organisms may not in themselves be pathogenic to man, danger lies in the fact that *hæmolytic streptococci*, in every respect similar to those which produce human disease, have been found in milk of affected animals, bulked milk being again most heavily infected.

Mastitis may be caused by the infection of the animal with *Streptococcus pyogenes* from persons handling the udder, this organism being responsible for scarlet fever and septic sore throat. Such an event occurs very infrequently but nevertheless it is a possibility to be borne in mind. *Staphylococcus aureus* may also cause mastitis, but normally the presence of this organism in milk will not affect the consumer. If suitable conditions allow these organisms free development, toxins may be formed in milk, the consumption of which may produce acute gastric troubles.

There have been many outbreaks of *septic throat* both in this country and on the Continent, some taking the form of definite epidemics. An example is the outbreak which occurred in Brighton, Portslade and Hove in 1929-30 during which 1,371 persons were affected, of whom 67 died. In many outbreaks, definite proof has been forthcoming that the udders of some animals in the herds investigated were infected with streptococci similar to those responsible for the outbreak. Streptococci of a scarlatinal type have been isolated in milk from cows suffering from mastitis, and it should always be remembered that *hæmolytic streptococci* may infect the udder without producing the usual signs of this disease.

If the infection is not severe, milk may appear normal. It is necessary to remember that clinically it is not possible to differentiate between the forms of mastitis which may be harmful to the consumer and those which are not, a bacteriological examination of the milk being essential for this purpose. Organisms from udders affected with mastitis are usually non-pathogenic to man, but the possible presence of pathogens in milk from such animals is again an indication of the need for the pasteurisation of all raw milk.

(c) CONTAGIOUS ABORTION. The presence of *Brucella abortus* in the milk of cattle infected with contagious abortion has been recognised for over 20 years. The incidence of this disease in dairy cattle varies between 40 to 50 per cent., while an average of 2 per cent. of affected cattle are excreting these organisms in their milk. This organism, which is now recognised as the cause of undulant fever in man, has been found in from 20 to 40 per cent. of raw milk samples, bulked supplies again being most heavily infected.

Large herds are generally infected, the disease in many cases being accompanied by permanent sterility of the affected animals. The udders of infected animals may be attacked by a mild form of mastitis which is not readily detected although causative organisms of the disease may be present in the milk. The udder is more frequently invaded than is the case with bovine tuberculosis, by far the largest number of organisms being found in milk soon after abortion has taken place, or after calving. The number present gradually diminishes as the lactation period advances. Some animals cease to discharge these organisms in their milk after a few weeks have elapsed but, on the other hand, the infection may continue for years or even become permanent.

Infected persons exhibit all the symptoms found in an attack of Malta fever, there being a very close relationship between *Brucella melitensis*, which is the causative organism of that disease, and *Brucella abortus*. Since 1917 many cases are known to have occurred in this country, while during this period there has been a steady, but slow, increase in the incidence of this disease. Since 1930 however, the increase has been more rapid, a fact which is due partly to improvement in diagnosis, and also to the greater attention which it has received. The slow increase in the annual number of cases is attributable to several factors, chiefly the absence of compulsory notification, the unfamiliarity of many medical men with the symptoms, the difficulty of diagnosis by clinical signs only, and the almost absolute confidence in the agglutination test, although this may be negative in many instances. The number of cases notified as "pyrexia of unknown origin" suggests that this disease may be more general than is suspected. Wilson has stated[1] that 400 to 500 cases of undulant fever occur annually in this country, the majority of these being due to milk-borne infection.

Sir Weldon Dalrymple-Champneys investigated 219 cases and obtained precise information regarding 149 of these. Of this latter total, it was found that raw milk had been consumed in 144 instances. Very few of these cases occurred in the London district, almost certainly due to the fact that the greater portion of the milk supplied in that area had been pasteurised. When the number of animals infected is considered, it would appear that there must be considerable resistance on the part of many persons which prevents infection, the disease developing only in those whose resistance is low. The majority of infections occur in adults and produce long-continued fever followed by a very protracted convalescence. It might be thought that so few cases should cause little fear of widespread disease. Unfortunately, however, there is little doubt that there have been many undiscovered attacks, the persons infected having been treated under an erroneous diagnosis.

(*d*) DIGESTIVE AFFECTIONS. The digestive affections of animals, causing the pollution of milk by faeces infected with *Bacillus enteritidis of Gaertner*, *Bacillus enteritidis* var *dublin* and *Bacterium typhi-murium*, have been responsible for extensive and serious outbreaks of food poisoning, both in this country and on the Continent. It has been found that the udder is sometimes invaded by the causative organisms although milk is generally infected by fæcal contamination. These organisms are capable of multiplying rapidly in the liquid, particularly if this has been indifferently cooled or stored under unsuitable conditions. In 1925 an extensive outbreak of milk-borne enteritis occurred in Aberdeen. This outbreak was found to be due to food poisoning organisms, 497 cases being notified, with one death. A similar outbreak, in which 132 persons were affected, was reported from Wilton, in Wiltshire, during 1936, most of the victims being children. In both cases, contaminated raw milk was the vehicle of transmission. Savage and Bruce White have reported that, in a study of 100 outbreaks of food poisoning, milk was the cause of infection in five, eight being traced to cheese and one to ice-cream.

Human beings may be attacked with gastric enteritis of the *dublin* type, a fever resembling paratyphoid being caused.

(*c*) OTHER MINOR DISEASES. Milk produced from animals suffering from foot and mouth disease, cowpox, anthrax, Johne's disease, or from diarrhœa or suppurative conditions, is not suitable for human consumption. In some of these diseases, the causative organisms may be excreted in the milk or may gain access to the liquid from an ulcerated teat or by means of faecal contamination. Cases have occurred when infected milk from animals suffering from these diseases has been the cause of human infection.

(2) **Infection by Organisms of Human Origin.** Although outbreaks of disease due to organisms of animal origin have attained serious proportions, the greater number of epidemics have been caused by human infection of raw milk supplies. The diseases spread by raw milk in this manner are typhoid and paratyphoid fevers, dysentery, diphtheria, scarlet fever and food poisoning.

(*a*) TYPHOID FEVER. This is one of the principal human diseases transmitted by milk. "Carriers" are the greatest danger and, unless such persons are particularly careful of their personal hygiene, the disease may be rapidly spread. Some 3 to 4 per cent. of typhoid patients become "carriers" for some period after their recovery ; in some instances this state may last for years. The causative organisms multiply readily in milk, the liquid becoming infected through contamination by personnel or from water supplies employed in cleansing the utensils.

Epidemics of typhoid fever due to the ingestion of infected raw milk have made fairly regular appearances, both in this country and abroad. The epidemic in Bournemouth and district which occurred in 1936 is still outstanding as a reminder of the results produced by the consumption of infected raw milk. In this epidemic, 718 persons were affected, of whom 400 were visitors to the town. Fifty-one residents died, as did a number of the visitors who contracted the disease, making a total of approximately 70 deaths in all. All the primary cases had consumed raw milk from one dairy which had obtained its supplies from a number of farms, and it is suggested that contaminated water had been used for washing the utensils. There are innumerable similar instances which may be cited and mention must be made of the epidemic which occurred in Montreal in 1927, this being by far the most serious outbreak reported during the past 20 years. Not only is this epidemic important because of its serious extent but its occurrence demonstrates the need for *efficient* pasteurisation. From March 1st to July 6th, 4,755 cases were notified with 453 deaths. Two peaks occurred, one in March and a further one in May. The infection was traced to milk supplied by one particular dairy which obtained its raw supplies from a large number of farms. Some of the milk passed through four receiving stations, one of which was found to be using water for washing purposes which was obtained from a polluted source. The milk was "pasteurised" on arrival, but this treatment was found to be unsatisfactory, the efficiency of the plant being nullified by bad management. Further, the foreman in charge was diagnosed as a "carrier" and was suspended from duty on April 16th. He could not, therefore, under these circumstances be held responsible for the second outbreak, the peak of which occurred in May. As more milk was received at the dairy on certain occasions than was processed, it is probable that a proportion was sometimes delivered untreated, this portion, unfortunately, having been polluted by the impure water supply previously mentioned.

(*b*) PARATYPHOID FEVER. Although milk-borne outbreaks of this disease are not so common as those of typhoid fever, they nevertheless do occur. The organisms multiply readily in milk, gaining access from the hands of infected persons or from utensils washed in polluted water supplies. In 1927, an outbreak caused by an infected dairy worker occurred in Hertfordshire, 166 persons being affected. The most extensive outbreak in this country occurred in the Epping district during February and March, 1930, 307 cases being notified, of which 233 occurred in the Epping Urban District. An infected milker was found to be the cause and when this person was detected and ceased handling milk, the outbreak subsided. In connection with this epidemic, Sir Alexander Houston has stated :

> "It is at least certain that if the Epping folk had drunk adequately pasteurised milk, there would have been no epidemic."

(*c*) DYSENTERY. Milk may become infected with dysentery in a similar manner to typhoid and paratyphoid fevers and, once the causative organisms have entered the liquid, they multiply rapidly. An outbreak in which 18 cases were notified occurred at Lynton in 1922, the source of infection being a dairy foreman who had suffered from an attack of the disease in 1918, and who was proved to be an active "carrier." Up to that time, milk had been regarded as an unusual medium for the dispersal of *Bacillus dysenteriæ*. In 1937 an outbreak due to milk-borne infection occurred at St. Andrews affecting 300 persons, while in 1938 a similar outbreak affecting 70 persons occurred in Bedford.

(*d*) DIPHTHERIA. Epidemics of milk borne diphtheria do not frequently occur. Milk may, however, become infected from persons suffering from the disease or from "carriers," while dogs and cats which possess a natural immunity may also act as "carriers," infecting either the milk or the utensils. When diphtheria is food-borne, the vehicle is practically always milk or one of its products. During the period 1907 to 1936, five outbreaks of milk-borne diphtheria were recorded in Glasgow. The frequency of diphtheritic infection of milk is, however, much less than that of scarlet fever.

(*e*) SCARLET FEVER. The causative organisms of this disease gain access to milk from persons suffering either from scarlet fever or from septic sore throat, or from the contacts of such infected persons. Organisms may also obtain entrance to the udder by way of the teat orifice, causing a type of mastitis and indirect infection of the milk. "Carriers" in the accepted sense of the term are not easily detected, although they undoubtedly exist. In addition, these organisms are capable of a virulent existence for some considerable time apart from an infected person. "Carriers" of *hæmolytic streptococci* may also infect the liquid, but these organisms do not multiply to any appreciable extent in milk at ordinary atmospheric temperatures.

Many outbreaks of milk-borne scarlet fever have occurred during the past 30 years. Pullinger, Kemp and Minett have stated that, in all probability, every large outbreak of this disease, and of septic sore throat, has been due to milk from cows whose udders have been infected with the specific human type of *hæmolytic streptococcus*. In particular, the outbreaks at Denham and Chelmsford, in 1935, must be mentioned. In the former instance, 100 persons contracted the disease, the majority of cases occurring in children, and there were two deaths. At Chelmsford, 1,600 persons were affected and six deaths occurred.

An extensive outbreak at Doncaster in 1936, due to cows which had been infected by a human "carrier," resulted in 186 cases of scarlet fever and 229 cases of "sore throat" being notified with three deaths. In each of these cases, raw milk was the vehicle of infection.

(*f*) FOOD POISONING. All the causative organisms of food poisoning infecting man may gain access to milk in a similar manner to other disease-producing bacteria. "Carriers" are most uncommon and the infection of utensils is usually due to persons suffering from a mild attack of the disease or from the infected fæces of animals or from rats, as will be mentioned later. These organisms multiply readily in milk at ordinary temperatures.

The other methods of infection, by rats or from water supplies, require to be considered.

(*a*) INFECTION BY RATS. Rats suffer from a form of typhoid caused by *Bacillus enteritidis* or *Bact. typhi-murium*. This rodent typhoid is infective to both human beings and cattle, many rats becoming either temporary or permanent carriers and infecting milk, water supplies or utensils.

Two outbreaks of milk-borne disease caused by *Streptococcus moniliformis* have been recorded. This organism is frequently present in the nasal organs of rats and the cause of these two outbreaks was stated to be due to the rat infection of milk.

(*b*) INFECTION FROM WATER SUPPLIES. It has already been mentioned that water used for washing utensils and the udders of cattle may be the cause of milk-borne outbreaks of typhoid, paratyphoid or dysentery when it has been polluted by human fæces. In addition, food poisoning organisms from such sources, or from rats may pollute the water supply. In practice, river water will be found to be most often contaminated although trouble may arise from the employment of shallow wells or surface supplies for dairy purposes if such are used without proper purification and chlorination. Water infected with *Bacillus enteritidis* or with organisms of the *dublin* type may, if used for drinking purposes, cause the animals to suffer from intestinal infections and the causative organisms may obtain entrance to the milk from fæces. Shaw has suggested, in conjunction with the Bournemouth outbreak, that cows may become infected with typhoid bacilli, but this has not been proved.

That milk is an ideal vehicle for the transmission of infection is obvious, particularly when it is remembered that approximately 200 outbreaks of epidemic disease due to infected milk have been recorded in this country alone since the commencement of the present century. It seems strange in these days of scientific achievement and public enlightenment that raw milk, such an excellent medium for the spread of disease, should still be regarded, in many quarters, as safe for human consumption. It is obvious from the epidemics which have occurred, that there is a heavy cost to the community in loss of wages, besides the individual physical suffering involved, while the expenses of local authorities in dealing with these outbreaks have been heavy.

Relations and friends of those who have suffered may no doubt ask why all milk is not pasteurised, realising that the process has prevented the further spread of disease. The only answer that can be given is that there is no law compelling such treatment at the present time. Public health officials cannot demand it—at least, not until after an outbreak has occurred and the mischief has been wrought. These harassed officials are then forced to content themselves with efforts to limit the further spread of disease. When lives are lost by accident, the daily Press refers to it as a calamity. How much more true is it to state that, when life is imperilled by the disregard of necessary precautions, an outrage has been and may still be perpetrated!

A quotation which states the position clearly from the public health point of view, the most vital aspect, aptly sums up the need of the moment. The Chief Medical Officer of the Ministry of Health has stated:

> "No amount of care in milking and distribution of raw milk can prevent it from being a danger to the customer. In other words, a clean, raw milk is not necessarily a safe milk. The only practicable way to reduce the risk to a minimum is by efficient pasteurisation or some other suitable form of heat treatment."

If one last word is needed, it is supplied by the following statement which appeared in an issue of *The Medical Officer* so long ago as June 15th, 1935:

> "Undoubtedly the right way to protect man from milk-spread tuberculosis is to free dairy herds from tuberculosis. This can be done, and to a limited extent is a feasible proposition. The Channel Islands have been freed from bovine tuberculosis; many selected

herds have been freed; but to free the whole of the cattle of this country is not feasible—or rather it is not feasible to try to do it at once. We must accept this, so we must look about for an alternative. This we have in pasteurisation, which is feasible. It is not ideal—nobody ever submitted that it was ideal—but it is feasible and can be reliable. But whilst we are using this palliative, we should get along with the main business of stamping out tuberculosis from milch herds. So pasteurisation must not be made an excuse for shirking the correct but more laborious and costly ideal."

CHAPTER III

CRITICISMS ANSWERED

As the process of pasteurisation has long been the subject of controversy, it is natural to expect that many objections might be raised against the process. Innumerable statements have been made, in some instances by people who ought to know better, with the object of discrediting pasteurised milk, but these are often due to ignorance. Such criticisms follow stereotyped lines and are easy to refute. Although the campaign against pasteurisation continues unabated, strangely enough there are no champions campaigning in favour of consuming water in its natural and unmodified condition. No voice is raised against the practice of sterilising water before it enters the public mains, while no apostle of nature demands that the public should drink the unpurified waters of our rivers. No persons concerned with the good of humanity collect rainwater and offer it to the public as a natural product, free from the dangers of unnatural treatment. Even when water is robbed of its mineral content by softening processes, there is no chorus of criticism, but rather applause from housewives. When people are advised by public health authorities to boil water which may be dangerous, that advice is invariably accepted without demur as sound and reliable. Indeed, the purification of water supplies in our large centres of population has resulted in an enormous decrease in the incidence of enteric fever and dysentery. When the same authorities advise the compulsory pasteurisation of milk, such advice is ignored and even ridiculed, although it has been proved that the incidence of milk-borne disease has been considerably reduced following the employment of this process.

Even with the best modern methods of production (as already shown), raw milk is more liable to contamination than is water. Nature did not elect that the human race should survive without struggling for its existence and in the process of survival, man has employed pasteurisation as a means of protection against the dangers of contaminated milk. And rightly so. Others, a minority it is true, but a powerful and persistent minority certainly, think otherwise, and voice objections to the process which require to be answered.

It is rather remarkable that a scientific process, introduced so many years ago, should arouse such controversy. Much of this is due to the confusion existing amongst the uninitiated as to what pasteurisation really means. Professor Porcher has defined it in the following manner, stating :

> "Pasteurisation of milk should destroy, by the suitable employment of heat, practically the whole of the bacterial flora and the whole of the pathogenic flora, if any, whilst introducing the slightest possible alteration in the physical structure of the milk, or in its constitution, chemical equilibrium and bio-chemical elements (diastase and vitamins)."

One of the commonest statements made by critics is that no proof is available that tuberculosis has ever been conveyed by raw milk. An argument such as this naturally leads one to suppose that its sponsors have never acquainted themselves with the results of investigations and biological examinations of raw milk carried out both privately and publicly throughout the country. Instances of such procedure have already been mentioned and there exist many others of a similar nature. Medical and veterinary opinion is generally agreed that the causative organisms of tuberculosis are widespread in raw milk and further, this being so, such milk, when consumed in its natural raw state, is liable to cause infection to the consumer. In this respect, Sir George Newman may again be quoted. In his Annual Report for 1933, he states :

> "The pasteurisation of milk in accordance with the requirements of the Milk (Special Designations) Order, 1923, if carefully and properly carried out, carries with it the immense advantage of making milk SAFE for the consumer without any impairment of its nutritive properties. It is significant that the extension of the practice of pasteurisation has synchronised both in time and place with a remarkable decline in the incidence and mortality of those forms of non-pulmonary tuberculosis which are attributable to the infection of bovine tuberculosis."

Lord Dawson of Penn, Lord Horder, the late Lord Moynihan, Sir Frederick Hobday, and Sir W. G. Savage stated on October 27th, 1933, that :

> "Raw milk as at present distributed for human consumption shows an average presence of living tubercle bacilli. Two thousand children

die annually from tuberculous infection of bovine (cow) origin, while many others suffer disabling and deforming illnesses. Pasteurisation, properly performed, reduces the risk of tuberculosis and other milk-borne infections to a vanishing point."

Attention must also be drawn to a Memorandum on Bovine Tuberculosis in Man, issued by the Ministry of Health, which states :

"Pasteurisation carried out in a suitable apparatus and under strict scientific control is capable of protecting the consumer from the danger of infection with the tubercle bacillus, and milk so treated appears to retain its valuable food properties practically unimpaired."

Lord Horder has further stated :

"Experience has shown that when pasteurisation (the heating of milk under conditions which ensure the destruction of harmful bacteria, yet leave the vitamins unimpaired) is generally practised, infection traceable to milk recedes almost to vanishing point."

Similar sentiments are expressed in a report of the Medical Research Council issued by the Ministry of Health in October, 1942, dealing with the increase in the number of cases of tuberculosis which has occurred under war conditions. This Report also lays stress upon the necessity for the compulsory pasteurisation of milk as a means of combating the increased incidence of this disease throughout the country.

The foregoing statements may be taken as a direct refutation of the argument that raw milk is not responsible for the conveyance of tuberculosis. Innumerable similar opinions are available which all critics of the process would do well to note. Indeed, as Wilson has so ably pointed out, if the facts regarding the transmission of bovine tuberculosis by means of milk are doubted, the whole germ theory of disease no longer holds good and the whole hygienic code based upon this theory must be scrapped.

There are innumerable reports by research workers detailing the results of feeding tuberculous milk to calves, pigs, guinea-pigs and other domestic animals which sceptics could peruse if they desired. One outstanding instance is the experiment conducted at the Hannah Dairy Research Institute. Briefly, it may be stated that of 36 calves fed on raw milk for a period of 12 weeks, 23 developed tuberculous lesions, while 37 fed on pasteurised milk showed no signs of the disease when slaughtered. It must be emphasised that tuberculosis, either human or bovine, is no respecter of human beings or animals, and, if infected milk can cause tuberculosis in cattle, the human animal is not likely to remain unaffected.

It is sometimes argued that an infection of bovine tuberculosis in early life will produce an active immunisation which is sufficient to protect the body against the ravages of human tuberculosis. In face of the available evidence, it is not easy to justify any method of indiscriminate immunisation which results in such a serious incidence of disease and actual loss of life. Surely, any vaccination against tuberculosis should be carried out by some more scientific and less dangerous process than by the distribution and consumption of raw milk containing unknown numbers of virulent tubercle bacilli: such a suggestion is contrary to all public health principles which exist for the prevention of disease wherever possible.

It is often stated that pasteurisation has not, in every case, destroyed all pathogenic organisms present in milk, as such organisms have, in some instances, been discovered after processing. It is not possible to disagree with this statement, but it must be emphasised that milk may be treated in two ways—efficiently and inefficiently. If the process is not conducted in accordance with recognised practice, either at too low temperatures or at the correct temperature for an insufficient period of time, then it is possible that some pathogenic organisms present may survive processing. *Efficient* pasteurisation, during which the milk is held between the correct temperature limits for the specified period, has been proved to be a sure means of destroying such organisms when present.

There is a good deal of statistical evidence to show that, in this country, there has been a more marked fall in the non-pulmonary tuberculosis death rate in cities where a large proportion of the milk is pasteurised than in those areas where only a small proportion of the liquid receives such treatment. In the United States of America, it is significant to note that milk-borne diseases have been practically abolished in the large cities, and such outbreaks are now almost exclusively confined to rural areas where most of the milk is consumed in its raw state.

It should never be forgotten that correct time and correct temperature are the prime requirements of efficient pasteurisation, and are essential for the destruction of pathogenic organisms likely to be present which are infective to man. The present Statutory requirements as to time and temperature afford the consumer an adequate margin of safety, as may be seen from Table 1.

TABLE 1

Organisms.	Destruction Time at 140° F.
Tubercle bacilli . . .	20 minutes
Diphtheria bacilli . . .	1 minute
Typhoid bacilli . . .	2 minutes
Dysentery bacilli . . .	10 minutes
Brucella abortus . . .	10–15 minutes
Streptococcus pyogenes . .	Under 30 minutes

To digress for a moment at this point, it is necessary to mention an anomaly which requires immediate rectification. Milk may be heated any number of times to any temperature within the vicinity of that required by pasteurisation and, further, may be sold without any designation or form of control. This abuse has in the past, led to great public disfavour and resulted in uninformed persons believing that the method was designed to hide the effects of insanitary milk production and handling. Quite a large proportion of milk treated in this manner may be pathogenically dangerous, and it is under these conditions that disease is likely to be transmitted. To remedy such an unsatisfactory state of affairs the compulsory licensing of *all* plants treating milk by heat is necessary in order to ensure the complete and satisfactory control of all processed milk.

Mention has already been made previously of the Montrea epidemic which, on *prima facie* evidence, would appear to have been due to pasteurised milk, although further investigation demonstrated that this was not so. In view of this and simila outbreaks, the opponents of the process have tried to profit from the fact that, in some instances, "pasteurised" milk has been responsible for epidemics, such milk having been "flash" pasteurised and not treated by the recognised processes. It has been found that, except in very few instances, such infectious disease transmitted have been due to the infection of the product by human agency. It has also been demonstrated that faulty plan of imperfect design and inefficient treatment have been the cause of some outbreaks. The human element is not infallible, and may be responsible for many mishaps, while man-made and man-maintained machinery may be far from perfect in every case. Such occurrences cannot always be avoided, although all reputable firms subject their plant to constant inspection for efficiency and require a clean bill of health from their employees.

It should also be recognised that, in many outbreaks of milk-borne disease, pasteurisation has prevented the spread of infection. To all unbiassed persons, this fact should supply sufficient proof of the efficiency of the treatment as a means of protecting public health. The increased employment of pasteurisation both in this country and in America has been followed by a considerable reduction in the incidence of non-pulmonary tuberculosis and by a diminution in the number of epidemics of milk-borne disease.

It is constantly stated that pasteurisation destroys the nutritive properties of milk. It must be remembered, however, that raw cow's milk is primarily designed as the natural food of the calf until weaned, and that it is not an ideal food for the human infant, as obtained from the cow. This difference must be taken into account when the results of experiments with calves are applied to the problems of human nutrition. Before considering evidence as to the falsity of such statements, the effect of heat on the nutritive value must be understood. Milk, when heated, undergoes certain changes which are influenced by the time during which it is exposed to the heating agent and the temperature attained during processing. In common with other liquids, milk expands when heated, the co-efficient of expansion being greater than that of water. Certain changes occur in its constitution. It loses viscosity, while a pellicle or skin forms on the surface of milk heated in contact with air at temperatures between 140° to 158° F., complete formation taking place when boiling point is reached, although this does not happen if the liquid is heated in a closed vessel. This pellicle contains a proportion of all the constituents of milk, but consists principally of lacto-albumin. Carbon dioxide is driven off and the bicarbonates are partially decomposed, causing a slight decrease in acidity, while the constituent calcium and magnesium salts are precipitated to a greater or lesser degree.

Milk which has been heated to a temperature of 165° F. fo 30 minutes will not coagulate with rennet although if temperatures between 105° to 165° F. are employed, coagulation wi occur, such action being retarded according to the temperature applied. This lack of coagulation is due to precipitation of calcium salts which render the casein present less easily coagulable The addition of calcium to heated milk hastens coagulation an there is no doubt that efficiently pasteurised milk will coagulat with rennet as easily as will raw milk. Indeed, pasteurised mil is now employed for cheese making where coagulation is essentia Lecithin and nuclein are said to be decomposed, and above temperature of 145° F. the fat globules are so disturbed that th cream-line commences to be affected. Ten to 20 per cent. reduction in cream-line may be expected in all milk correctly processe but heat does not appear to have any effect upon the compositio of the milk fat which is chemically unaltered. The enzymes ar entirely destroyed if a temperature of 175° F. is maintaine for a short period. Without doubt certain enzymes present i milk, particularly phosphatase, are destroyed by pasteurisatio although some remain unimpaired. All the present availab evidence shows that the enzymes of milk are of little importan from the point of view of human nutrition.

At temperatures above 145° F. the percentage of diffusib calcium is reduced and if the temperature of the milk is raised 150° F., the albumin begins to coagulate, increased coagulati being observed as temperature rises. The heating of milk pr duces a taste particularly noticeable to those possessed of sens tive palates. This taste varies according to the temperatu employed during the heating process. The *flavour* of pasteuris milk may be slightly different to that of raw milk due removal, by filtration and heating, of volatile substances deriv from the cow and its surroundings. This alteration is d cernible to few consumers, and even experts cannot say wi certainty whether or not a sample of milk has been pasteurise Pasteurised milk possesses little if any "cooked" flavour an if present, this is normally hard to distinguish. High temperatu employed during the sterilisation process produce a "burnt taste, due to the caramelisation of milk sugar, the liquid beco ing brownish in colour. The *colour* of milk treated by the hold method may perhaps appear to be more dead-white, but with t high-temperature short-time process the taste and colour of the liquid are little affected.

At 145° F. the freezing point of milk is slightly raised and acidity somewhat reduced whilst prolonged heating at this temperature or over destroys any bacteria which it may contain, according to the period of heating and temperatures attained. Toxins of such organisms are destroyed at relatively low temperatures. After boiling, the bacteria which remain consist entirely of spore-forming organisms and certain varieties of bacteria highly resistant to heat. The phosphates are precipitated by prolonged heating at high temperatures, while vitamins C, B_1, A and D are destroyed in that order. Milk which has been heated forms a finer coagulum or curd in the stomach than does raw milk and is therefore more digestible.

It should be noted, however, that all the changes outlined do not occur in efficiently pasteurised milk, as the temperature limits of pasteurisation (145° to 150° F. or 162° F.) and the period of heating (30 minutes or 15 seconds), reduce the effects of heat on milk. Certain changes do occur, however, in the chemical constitution of pasteurised milk. At 145° F. the albumin content is not affected, but at 150° F., 5 per cent. is precipitated, the equilibrium of the mineral constituents being upset. A proportion of the calcium and phosphorus content is precipitated in an insoluble form. The diminution of the quantity of these salts present after pasteurisation amounts to approximately 5 per cent. Proteins and enzymes begin to be affected, the enzyme phosphatase in particular being entirely destroyed during processing, while the cream-line is reduced. There will be between 8 to 10 per cent. reduction in the cream-line if milk is heated for 30 minutes at a temperature of 145° F. At 146° to 148° F. for a similar period, the average decrease in the cream-line will be between 20 to 30 per cent. This decrease will rise to between 40 to 50 per cent. at 150° F. The cream-line may, however, be conserved by the rapid cooling of hot milk, the critical temperatures being between 110° F. and 60° F. It is preserved if rapid cooling is practised between these temperature limits. Also, the lower the temperature to which milk is cooled, the better will be the cream-line.

The *vitamin content* of milk is altered by heat to a varying degree. Vitamin A is not seriously influenced by pasteurisation,

although a slight loss has been reported by several investigato
neither is vitamin B_2. Stassanised milk shows a smaller loss
vitamin A content than does holder-pasteurised milk. Vitan
B_1 is not absolutely heat tolerant, as evidence shows that p
cessing reduces the amount present by between 10 to 20 per ce
Vitamin C is heat sensitive to a greater or lesser degree, t
amount destroyed depending upon previous exposure to lig
particularly sunlight, and the degree of oxidation which takes pla
this being accelerated by the catalytic action of certain meta
Usually, milk loses from one-fourth to one-third of its vitamin
content during processing. It should be noted here that
metals normally used for the construction of modern plant, su
as stainless steel, exert very little catalytic action. The destr
tion of vitamin C during treatment averages 20 to 40 per cent.
the vitamin present in raw milk prior to treatment, when heated
aluminium containers in the presence of air. If copper w
used under similar conditions, the loss would be as high as 80
90 per cent. Experiments carried out at the Cornell Universi
U.S.A., have shown that it is possible, under commercial con
tions, to maintain in milk processed by the low-temperatu
method as high a vitamin C content as is present in raw m
of the same age. Careful handling of the milk by providi
protection from light and air and the use of modern plant redu
such losses considerably. High-temperature short-time p
teurisation is definitely less harmful to the vitamin C content
milk than is the low temperature process. Experiments ha
shown that vitamin D is not affected by processing and there
no evidence to show that vitamin E, which is present in very sm
quantities, is affected by pasteurisation. Except as mention
above, the nutritive value of milk treated by the short ti
process is similar to that dealt with by low temperature p
teurisation. From the foregoing, it would appear that t
advantages to be derived from a safe, long-keeping milk mo
than outweigh the so-called disadvantages, particularly as th
is no evidence to show that the nutritional value of such milk
materially affected.

It is a peculiar fact that, since the raw milk advocates cann
demolish by criticism the principal advantages of the pasteuris
product, they are compelled to force the argument in other wa
The man in the street has little knowledge of vitamins ;

understands that they are a "something" inherent in various foods. Consequently, when statements are made that vitamin C is destroyed in processing, he may well believe that pasteurised milk has lost one of its main attributes. Actually, the quantity present in raw milk is not large, certainly not sufficient to satisfy human requirements, and this deficiency must therefore be made good by products other than milk. Obviously, the diminution of vitamin C through pasteurisation is not such a terrible catastrophe as it is so often proclaimed to be by critics of the process. It should be noted that any loss in the vitamin C content of milk following pasteurisation is not primarily due to the application of heat during processing, but to previous exposure of the milk to light, particularly sunlight, the effect of which is intensified if the liquid comes into contact with copper.

Another argument often employed is that the amount of calcium and phosphorus present is reduced during processing. This may be so, but one ought to remember that milk contains approximately three times as much calcium and five times as much phosphorus as does human milk, although the latter is designed for feeding babies. Cow's milk, now so extensively used for human consumption that its original purpose is apt to be overlooked, was designed as a food for calves and not for infants, therefore the reduction of the calcium and phosphorus contents in processing is not the serious matter critics would have the public believe.

Milk possesses many qualities which render it an extremely valuable food, and discussing the question of the destruction of these qualities, Dr. Hamill, in his valuable report on pasteurisation, has stated :

> "The nutritive properties of milk in conformity with its physical and chemical properties do not appear to undergo any appreciable change as a result of pasteurisation, except in respect of anti-scorbutic properties. It has already been mentioned that the anti-scorbutic vitamin in milk is impaired by pasteurisation. Fortunately, however, this defect in pasteurised milk is readily corrected by the administration of anti-scorbutics such as orange juice."

Dr. Hamill adds that the important positive advantages which accrue from pasteurisation may be regarded as out weighing any possible slight depreciation in nutritive value.

Dr. H. C. Corry Mann, addressing the World Dairy Congress 1928, regarding his experiments, said :

> "For over three years past, low-temperature pasteurised milk h been given to children under the age of two years without a ration orange juice. There has been no incidence of scurvy. No increase growth rate and no improvement in nutrition has ever been noted fr the addition of orange juice to a diet of milk pasteurised by th method."

Speaking of the startling improvement in weight and height growing boys fed with a sufficient daily diet plus 1 pint of mi daily, Dr. Mann further stated :

> "This improvement was most successful when fresh cow's mi recently *pasteurised*, from a clean and reliable source, formed t additional item of food, and such improvement both in weight a height increments was not a temporary phase, but was maintain over a period of one, two and three years."

During the last few years, a large number of scientifical controlled experiments have been carried out to ascertain a existing nutritional differences between raw and pasteurised mil Calves fed on the pasteurised product have been found to ga slightly in weight per day when compared with those fed on ra milk, while, in addition, there was freedom from infection tubercle bacilli. Experiments carried out by the Milk Nutriti Committee in 1935-36, during which period many thousands school children in different districts were given either raw pasteurised milk, have shown that so far as nutrition is concerne there are no constant differences between the growth rates children receiving milk, whether raw or pasteurised. The Chi Medical Officer of the Ministry of Health in his Report for 193 referring to these experiments, stated :

> "the enquiry provides important information . . . which rei forces the steadily accumulating evidence that pasteurisation has significant effect on the nutritional value of milk."

These testimonies are important as they were made after period of prolonged and careful investigation. It must emphatically stated that scientists and research workers hav discovered that, if the process is correctly applied, milk remai milk and retains practically its entire nutritive value, and an losses resulting from processing cannot be differentiated by actu feeding experiments.

Critics also state that the destruction of lactic acid organisms may conceal the fact that milk is deteriorating in quality. Such an argument may be easily disproved. Milk is generally consumed on the day on which it is delivered, to keep it for more than 24 hours without some means of refrigeration being most unusual. It has therefore no time to become sour. Further, if milk is efficiently pasteurised, sufficient lactic acid organisms, which possessed reduced vitality, survive the heating process to ensure that the product will sour before putrefaction commences. Fortunately, the majority of lactic acid organisms are destroyed by processing; this reduction in number assists in prolonging the life of milk, an advantage which should appeal to any but the most biassed person.

To the ordinary producer, it makes little difference whether or not his milk is processed after it leaves his premises, and bonus payments for clean milk production in this country have shown that cleanliness of production can only be stimulated by financial inducement and not by any fear of compulsory pasteurisation. Yet the agricultural community quite frequently state that compulsion would result in the standard of raw milk production being considerably lowered. Apart from the fact that no standard for ungraded raw milk exists other than that laid down under the National Milk Testing Scheme, and that much milk now produced is comparatively poor from a hygienic point of view, it must be borne in mind that the production of clean, raw milk can be most adequately assured by requiring a pre-pasteurisation standard of cleanliness for all such milks to be subsequently processed. In New York, a pre-pasteurisation standard of not more than 300,000 bacteria per millilitre is required. If a similar standard was required in this country, many supplies of milk would be graded as unfit for processing. Recent bacteriological studies have proved that clean milk is quite as important for pasteurisation as for distribution in its raw state. Carelessly-produced milk cannot be efficiently pasteurised, it having been demonstrated on innumerable occasions that many organisms found on dirty dairy utensils possess the special property of resisting destruction by temperatures which kill the ordinary forms of non-sporing bacterial life. Steam sterilisation for all milk utensils at the point of production will reduce or even practically eliminate the number of bacteria surviving pasteurisation. The sterilisation of milking machines is particularly necessary as, if neglected, millions of heat-resistant organisms may be added to milk. It has been stated that any farmer who produces clean milk may decide to relax his precautions when his milk is mixed with other milk of a lower standard. This may occur, but it is not an argument against pasteurisation but rather against the bulking of milk. Though pasteurisation may make a dangerous milk safe, it can never render a dirty milk clean.

Many persons fear that the compulsory pasteurisation of all supplies would result in the disappearance of large numbers of small dairymen from business. There appears to be no reason for these fears. Plants for the efficient treatment of milk are obtainable in all sizes at prices allowing installation even by the small producer-retailer. The statement often made that an unknown number of small retailers would be forced to give up business is surely no reason why the process should not be compulsory. No other tradesman is allowed to sell a polluted or diseased foodstuff without suffering the consequences. Any distributor, whether large or small, if unable or unwilling to supply his customers with a clean, safe milk, is better out of business. The introduction of the Milk and Dairies Order, in 1926, in districts where it has been strictly enforced, has not caused any producer or retailer to cease business. Similarly, any Act or Order enforcing compulsory pasteurisation would have little effect *per se* upon small dairymen.

Universal, compulsory pasteurisation will not be practicable for some time, but its advent would mean the production of cleaner milk generally, as the bulk of it would have to travel to urban areas for treatment. The day of the small, inefficient dairyman is passing and the result will no doubt be the combination of several small distributors with consequent benefit to the consumer. Such persons are able, should they desire, to procure sufficient milk for their needs, already pasteurised from one of the large processing companies and do not, therefore, require to install expensive plant for this purpose. The recent White Paper (Cmd. 6454—1943) envisages the provision of independent pasteurising plants by local authorities in order to handle milk for small dairymen, and where it proves impossible for suitable arrangements to be made by the trade itself, such public bodies are to be allowed to safeguard the interests of small producer-retailers and dairymen by arranging suitable means of treating their milk.

In spite of all their arguments, the opponents of pasteurisation have not yet brought forward any alternative process which can guarantee the wholesomeness of all milk. One feature of many of the criticisms advanced is the fact that their authors appear to confuse, either wilfully or through ignorance, the pasteurisation process with that of sterilisation, in many instances speaking of "boiled milk." This is quite often the case amongst many members of the agricultural community. It is probable that in such quarters the meaning of efficient pasteurisation is not understood. It must be emphasised that pasteurisation is not sterilisation which indicates the complete destruction of all microbic life, which is not desired. The chief desideratum is to destroy all disease-producing organisms and to retain sufficient acid-forming bacteria to sour the milk, thereby preventing the development of putrefactive organisms. It cannot be too strongly emphasised, from all points of view, that the advantages to be derived from processing are so great as to offset all criticisms levelled against the method by raw milk advocates; criticisms, incidentally, the greater number of which are prompted either by ignorance or, more usually, personal interest.

The present position is that the agricultural community are strongly resisting, in their supposed interest, the introduction of either optional or compulsory pasteurisation. On the other hand, public health authorities are generally in agreement that such treatment should be compulsory or, alternatively, that the sale of infected milk should be subject to prosecution and fine, and, not as at present, to public assistance and compensation. Producers cannot submit to a measure of protection and also demand immunity from punishment for spreading disease.

Compulsory pasteurisation will only come at the instigation of the authorities concerned and, when it does arrive, as it most certainly will, both the public and the milk trade may rest assured there are good and sufficient reasons for such compulsion. Some years ago, the Committee on Animal Diseases of the Economic Advisory Council recommended that compulsory pasteurisation should be introduced, but no steps were taken until 1944, when the Minister of Food was empowered by Defence Regulation 55G to make Orders specifying that milk sold in areas where deliveries had been zoned should either be “Tuberculi Tested” “Accredited” milk from a single herd, “Pasteurised or “Sterilised.” If and when compulsory pasteurisation i introduced, both the cleanliness of raw milk and its subsequen treatment must be more satisfactory than at present. Th essentials are a clean milk for processing, the licensing of al pasteurisation plants, medical control of personnel, frequen inspections of plant and premises and the efficient laborator control of processing by means of bacteriological methods an the phosphatase test.

There is without any doubt a growing demand for safety in th form of pasteurised milk. For years the public have waited fo some legislative measure which would provide compulsion, and in waiting, have seen the spread of disease and succession o epidemics causing suffering, maiming and killing amongst thei fellow-men, all of which could have been avoided. Surely it i time that the existing state of affairs was altered, particularly a outbreaks of disease will continue to occur until pasteurisation i universally applied. It is a matter of chance when and wher the next epidemics will show themselves; that these *will* occur i certain so long as unpasteurised milk is sold.

CHAPTER IV

PLANT DESIGN

THE continued increasing application of pasteurisation renders it the duty of the public health official and distributor to thoroughly understand the various types of plant provided for the purpose, although a knowledge of defects which may arise, their causes and eradication is essential. Considerable attention has been paid to the process from a nutritional aspect and from the safety point of view, while frequently the technical aspect has failed to receive the attention it merits.

What is really remarkable is the serious lack of proper appreciation of the principles involved in layout, design, construction and maintenance of such plants on the part of those persons responsible for their operation and control. It should again be stressed that all pasteurisation as practised in this country is *not* efficient, stricter control being required if the public is to rely upon the safety of milk so treated.

Licensing authorities have discovered that many of the plants now in use are treating milk in an inefficient manner the principal defects found being unsuitable premises, apparatus of unsatisfactory design, insufficient insulation of the holders, exposure of milk to air-borne contamination after treatment, unsuitable methods of temperature control, and, as might also be expected, mismanagement.

Before dealing with the details of plant design, it is necessary to emphasise that the prime essential of processing is that milk requires to be heated once only, to a temperature of 145° to 150° F., and to be retained between those temperature limits for precisely 30 minutes; it must then be immediately cooled to a temperature of not more than 55° F., but preferably lower. The short-time process which is accepted as suitable by the Minister of Health for the production of pasteurised milk is discussed in Chapter VIII.

The pasteurising depot and its plant require to be considered as separate units. These are the buildings, layout and the apparatus provided.

(1) **Buildings.** The housing of the plant is co-related to the

design of the apparatus and is equally important, as, in order
provide for satisfactory treatment of milk, suitable premises
essential. These should be located on a site which affords e
communication by rail and road. Both the internal and ext
nal appearances of all buildings require to be carefully consider
An ugly exterior is likely to give the observer an unfavoura
impression of the interior, however well designed and equipp
that may be. Elaborate architectural effects for external
should be avoided; generally speaking, the simple design
the best, being most effective, least expensive and most wo
manlike. It should, however, possess distinctive features entir
its own and the exterior and interior should harmonise. T
utmost tidiness should prevail in all parts of the premises
otherwise the dairy cannot claim that the milk has been treat
under the best possible conditions. Not only does appearan
ensure an advertisement for the firm housed in the buildi
but it has a great influence upon the economic efficiency of
plant. Employees who work in good surroundings quickly obta
the impression that a quality product is demanded and there
then no tendency to shirk their responsibilities.

Sufficient floor space is a primary necessity and in many premis
this is totally inadequate. Lack of space is not so much due
inherent faults present in the building, or to the restriction
available accommodation, but rather to want of thought in
lay-out of apparatus. In order to overcome lack of space, man
facturers of pasteurising plant sometimes tend to crowd togeth
the various components, locating these either too close togeth
or too near the walls or the ceiling. Consequently, difficult
arise regarding management, cleansing and inspection. Adequa
space is essential for ease of working and in order to assist venti
tion, while in addition, an allowance should always be made
future extension. Many plants become overcrowded with ap
ratus as trade expands on account of failure to allow suffici
space for future development when the building was first erect

Sufficient air space and *efficient ventilation* are essential and
particularly important for the benefit of employees on accou
of the tendency to a high degree of humidity which is alm
invariably present in premises where steam is employed for tr
purposes. Excessive moisture prevents the maintenance
comfortable conditions, condensing on ceilings and dropping

to the apparatus or gaining entrance to the milk. Re-contamination of the product may be caused in this way unless the ventilation provided is sufficient to carry from the building all escaping steam. In addition, moisture if excessive will eventually damage woodwork, equipment and the internal paint. Condensation is always more excessive during cold weather, but may be overcome to some extent by the provision of insulated roofs and double glass skylights. Windows should be capable of being opened and, what is more important, they should be kept clean in order that they may serve the purpose for which they were originally provided. Proper ventilation and window openings of suitable sizes allow the dispersal of and freedom from noxious odours and effluvia which should never be present in a well-conducted dairy.

Window openings are frequently insufficient in themselves to afford proper ventilation and exhaust fans require to be provided. Steam from bottle-washing machines and similar steam producers can be conducted directly into the open air while the employment of steam radiators during cold weather will considerably alleviate any nuisance from condensation. Probably the ideal system of ventilation, particularly for large plants, is *controlled air conditioning*. This system maintains suitable temperatures either in hot or cold weather, restricts humidity, gives satisfactory ventilation and is clean in action, only washed and filtered air entering the processing rooms. Certain points require to be borne in mind when the provision of this type of ventilation system is considered. The amount of excessive moisture to be removed and the location of the sources of such moisture together with the nature of the equipment producing same must receive primary consideration. The length of time it is being produced by the apparatus also has a bearing on the problem while the maximum humidity and temperature which is to be allowed must also be decided. These conditions, of course, depend upon the maximum humidity and the high and low temperatures prevailing outside the plant.

Natural and artificial lighting is extremely important so that proper supervision may be given to the plant and in order to provide facilities for inspection of all stages of processing and of recording instruments. Good lighting assists in the maintenance of hygienic conditions by rendering it possible to ensure that the machinery and premises are properly cleansed, while employe work better in well-lighted surroundings. Accidents which ten to occur on account of the wet, slippery condition of the floo may often be prevented if lighting is satisfactory.

All windows should be as large as possible, the factory ty with steel frames being preferable, metal being more durable a of better appearance than wood. The top portion of all windo should be designed to open inwards, and the frames shou be treated, prior to painting, with a good anti-corrosive fluid. wooden frames are fitted they should be frequently paint otherwise they will deteriorate rapidly. Care in siting windows that light is evenly distributed throughout is important and t window area should never be less than 10 per cent. of the flo space. It is usual to provide skylight windows in one-stor buildings and in top-floor rooms, when the light is more even distributed and less artificial lighting will be necessary.

The intensity of *artificial lighting* must be varied according the work which is carried on. In the vicinity of the pasteurisi plant, that is storage tanks, preheaters, holders and cooli units, 30 to 35 foot candles are required. Such powerful lighti is, however, only needed during cleansing operations, 15 to foot candles sufficing while actual processing is in progress, wh the main duty of those in charge is to watch gauges and recordi instruments, all of which should be separately and specia lighted. Adjoining tipping tanks and bottle washing machine 15 to 20 foot candles will suffice, special lighting being provided the inspection and handling of bottles entering and leaving washing machines. Localised lighting somewhat above general level should be provided in the vicinity of bottling a capping machines. The normal tungsten filament lamps daylight blue lamps may be employed with success, but excee ingly satisfactory use can be made of mercury-discharge lam which give a silvery light of marked penetrative power. Reco mendations were recently issued by the Home Office Depa mental Committee on lighting in factories and much useful inf mation can be found in that Report. Fittings should be select with a view to their resistance to moisture, while for da situations, waterproof lamps are advised. The efficient lighting dairy plants should be rigidly enforced by controlling officials a the plant operator should give careful consideration to this questi

Obviously a good *roof*, without any dust traps or loose plaster, is essential. This can be used to provide additional natural lighting.

Walls should be constructed of brick, concrete *in situ* or concrete blocks, rendered internally with some hard, impervious material to a height of not less than 6 feet above floor level in order that cleansing may be facilitated. Glazed bricks or tiles are ideal for internal surfaces although a good cement rendering is cheaper and quite satisfactory. The walls of processing rooms should not be less than 12 to 14 feet in height, and although it is not essential that the impervious surface should be carried to the full height of the room, this is desirable, if the cost is not too excessive. An impervious finish facilitates cleansing and makes for economies in paint. The junctions of walls with floors should be rounded off in order to prevent any accumulation of dirt and to simplify cleansing operations.

The internal *painting* of the premises requires careful consideration. If the building is constructed with cavity walls, the problems which may arise from interior painting are not involved. Should the walls be of solid construction, it may be necessary to waterproof the internal surfaces, otherwise any exudation of moisture from the brickwork may cause the paint on interior wall surfaces to blister, crack or peel. For normal use, a suitable oil-base interior wall and ceiling paint should be employed, white or light pastel shades being preferable with either an egg-shell or gloss-type finish. The latter type is easiest to clean and is more resistant to the absorption of moisture than is a matt finish.

White paint is extremely useful for the interior surfaces of dairy premises, possessing excellent light-reflecting qualities while the rooms appear lighter than is the case when darker paints are employed. White paint readily shows dirt and requires to be kept clean, inducing greater sanitation within the plant, while this colour also makes rooms appear to be larger and airier. Light cream paint gives the walls a warmer appearance, however, and its light-reflecting qualities are nearly equal to those of the white variety. A dado of deeper colour is advisable at the base of walls as this provides darker areas where most splashing is likely to occur and where the walls are most likely to become rapidly soiled.

When excessive heat or humidity is present, ordinary paints cannot be expected to withstand satisfactorily these exacting conditions, which exert a marked yellowing and discolouring influence. In such instances, a dammar-base material should be employed. Dampness in the atmosphere, due to steam, encourages the growth of fungi or moulds, the spores from which may obtain entrance to the milk. As such growths are very undesirable intruders, a paint designed to inhibit their development should be used, and such painted surfaces should be frequently washed down with one of the sodium hypochlorite preparations now available. Free chlorine, which is one of the best and most poten destroyers of bacteria and fungi, is thus provided. Portions o wall or ceiling areas may be constructed of steel or other meta and, before painting, these surfaces should receive a coat of rus preventative. Galvanised iron surfaces should be washed firs with copper sulphate solution and then receive a coat of specia galvanised-iron primer before they are finally painted.

Frequent painting is essential to protect exposed surfaces from moisture and in order that an attractive, well-kep appearance, so essential to a modern milk processing plant is provided. Frequent re-painting is economical as this restore oil to the pigment before it becomes subject to excessive dryness and consequent peeling.

The construction of the *floor* is extremely important and requires serious consideration as it has to be strong enough to resist the wearing action of traffic such as milk cans and truck and also the chemical action of caustic solutions, detergents and hot water emptied from the equipment. Milk fats and acid which come into constant contact with its surface exert a deleterious effect. Whatever type of floor is employed, it should exhibit a continuous smooth surface with no hollow places, should be easy to clean and be safe upon which to work. Hard wear and the action of detergents and milk acids will cause cracks o crevices to form eventually in concrete floors while the groutin material in tiled or brick floors will deteriorate from simila causes. As these defects develop, deterioration becomes mor rapid and difficulty will be experienced in cleansing the floo surfaces. Washing solutions are absorbed in the crevices and, a the water evaporates, the salts remain and become more concentrated, eventually damaging the floor still further. Ho water causes unequal stresses in floor surfaces and will ultimately destroy the bond existing between these surfaces and the concrete beneath. The most serviceable and cheapest material for the construction of floors is good quality *concrete* which possesses most of those properties which resist destructive influences for some considerable time, always provided it is constructed of first-grade materials and is adequately drained. Particular attention should be paid to the prevention of pools of water forming upon its surface. A minimum quantity of water must be used for mixing the concrete, consistent with a workable mixture being produced. An excessive amount of moisture will lower the quality of the concrete while too much trowelling causes the fine material to rise to the surface and the finish will not withstand abrasion and hard wear. In order to render a floor non-slippery, carborundum crystals may be mixed with the cement finishing coat. When completed, it is desirable to treat the floor surface with a solution of magnesium or zinc fluosilicate, sodium silicate, aluminium sulphate or zinc sulphate to give the concrete increased immunity from acid attack. These chemicals react with cement to produce a harder or denser surface. After the application of any of these solutions, the floor should be treated with two coats of boiled linseed oil applied when warm, care being taken to remove any excess oil before stickiness develops. One of the more suitable bakelite-type enamels may be employed in place of linseed oil if desired. These materials are quick drying and provide a hard, abrasive resistant finish.

Floors of unloading platforms, milk receiving and can-washing rooms, which are subject to heavy wear, should be strengthened and protected by embedding metal plates in the concrete when the floor is being constructed. These plates consist of parallel steel bars which are held together with tie rods, and they are laid on the floor base before it hardens. The spaces between the bars are filled with concrete. *Tiled floors* are quite suitable for pasteurising and bottling rooms, being moisture resistant while possessing an attractive appearance. In addition, they are easily repaired without exhibiting any signs of patching. A good quality tile will resist the action of lactic acid and hot water and, if properly laid on a concrete base 5 to 6 inches in thickness, will withstand much heavy traffic and hard wear. With tiled floors, the grouting material is the weakest point, and for this reason special substances such as phenolic resin or plasticised sulphur compound should be used for this purpose. *Vitrified brick* is sometimes employed for those parts of the premises where floors are subject to hard wear and tear, as in washing and milk receiving rooms. This type of floor is quite satisfactory if properly laid, but the grouting must be acid proof if it is to be entirely durable. To give greater thickness and rigidity to the floor, the bricks may, if desired, be laid on edge.

Floors should be given a sufficient slope to prevent any accumulation of water on their surfaces. If sufficient fall is not provided or the floor drainage is unsatisfactory, working conditions will become most disagreeable. A slope of ¼ to ½ inch per foot is essential, with an increased fall near the drain outlets through the external walls. This method is preferable to the provision of floor channels covered with metal gratings which are difficult to maintain in clean condition. Waste water should discharge to the drain by means of a grease trap in order that any fat present in the drainage water may be collected.

The disposal of *waste matters* from dairy premises is one which has raised many problems, particularly in country districts where no sewers are available into which such wastes can be discharged. The effluent generally consists of a diluted solution of milk and detergent used for cleansing purposes, and this is an extremely unstable liquid which undergoes rapid decomposition at normal temperatures. The discharge of such solutions into country rivers and streams cannot be countenanced before some form of purification has taken place, particularly when it is noted that a dairy effluent which contains 1 per cent. of milk causes almost three times as much pollution as would a similar volume of domestic sewage. Further, the disposal process is complicated if the usual creamery manufacturing processes are carried on. The volume of effluent requiring to be treated may be reduced considerably if some form of separation is practised, as those waste waters which are practically clean can be discharged direct to the river or stream while the more polluted liquids receive further treatment before discharge takes place. The constant discharge of waste water is not possible in any plant and provision for storage of one day's supply in a collecting tank is essential.

All the normal methods of sewage treatment, recognised both in this country and abroad, have been tried with varying success, but it has been realised that the satisfactory final disposal of creamery effluents is a most difficult task. The Water Pollution Research Board have carried out experiments with a plant capable of dealing with 30,000 gallons of effluent daily. The waste waters are strained and enter a small collecting tank from which they are pumped to one of two holding tanks, each of which is capable of containing a day's supply. Each tank is funnel-shaped and is fitted with a steam coil, thermostatically controlled to maintain the temperature at 86° F., and provided with pipes through which air is blown to maintain aerobic conditions. Aeration is continuous, and when the steam and air are cut off after 24 hours' treatment the separated material quickly settles to the base of the tank. Outlets are provided at three levels so that the clear effluent can be discharged before the whole of the separated material has settled to the base. Material still in suspension is then removed by another fixed filter and the liquid passes to two percolating filters, each of which is 36 feet diameter and 6 feet in depth, which are arranged in parallel. From these filters, the effluent can be discharged to the nearest stream. The sludge which remains is transferred to a sludge digestion tank and is finally dispersed over adjoining land. The effluent of dairy wastes treated in this manner should possess an average B.O.D. (Biological Oxygen Demand) of less than 1 part per 100,000.

Doors, especially those in external walls, should be limited to the number actually required. Care should be taken to prevent the entrance of flies into the plant, both internal and external doors being of the self-closing variety for preference. They should be stoutly made in view of the hard usage they are likely to receive.

The *water supply* is of vital importance. Not only must a copious supply at low temperature be available, but such water should be faultless both from a bacteriological and chemical standpoint. Houston has recommended the following *bacteriological standards* for water supply. There should be :

(*a*) Less than twenty organisms per millilitre (gelatine at 20° to 22° C., counted on the third day).

(*b*) Less than five organisms per millilitre (agar at 37° C., counted after twenty-four hours).

These standards may be relaxed somewhat if the results of th coliform examinations are satisfactory.

(c) Less than one-half the samples should contain typical *Bacillu coli* (lactose +, indol +) in 100 millilitres.

The standard of *chemical purity* required in water used fo dairy purposes should at least be equal to that for drinkin water. This may be easy of attainment if the supply is take from the mains, but is not always possible of achievement whe obtained from a well sunk on the site, although if an artesia well is bored no difficulty should arise. The water should b clear and odourless with as low a temperature as possible. I should not contain more than mere traces of ammonia or any nitrites. Nitrates (N_2O_5H) should not be present in greater percentage than 0·003 while the water should possess the least possibl amounts of chlorides with only traces of phosphates present. I more than 0·1 part of oxygen is absorbed by potassium permanganate, such water should be looked upon with suspicion.

Water supplies in this country vary in hardness, and the problems of the dairy industry which arise through *hard water* ar often considerable. Water in its natural state may contain salt of lime and magnesium, chiefly carbonates and sulphates, althoug occasionally chlorides and nitrates are present, in varying pro portions according to the source of supply. These impurities exist either in suspension, in the form of an emulsion or as dissolve gases and chemical salts. In the processing plant water is require for a variety of purposes, but chiefly for washing and boiler use and it is important that it should be free from such salts as are likely to cause film or scale. One of the difficulties facing those who are forced to use hard water is the presence of dissolve chemical salts which can only be eliminated by a combine chemical and mechanical process which will soften the wate and render it fit for industrial use. A suitable water softene should, therefore, be a standard fixture in all processing plants in order to prevent higher upkeep and production costs due to scale and sludge removal, fuel waste, clogged pipes, discoloured water and loss of time with consequent curtailment of production.

The *lime-soda process* allows the removal of temporary hardness by the addition of a sufficient quantity of lime. Twice as much lime is required for the removal of this type of hardness when caused by magnesium bicarbonate. Permanent hardness, due to calcium salts, is removed by the addition of soda ash to form calcium carbonate, which is precipitated. Permanent hardness due to the presence of magnesium salts is removed by the addition of the required amount of lime and soda ash. Water may also be softened by the use of *caustic soda* alone, or a combination of *caustic soda–soda-ash* which will precipitate calcium carbonate or magnesium bicarbonate, caustic soda being added for the removal of temporary hardness. Permanent hardness due to calcium salts is removed by sodium carbonate, as in the case of the lime-soda process. The *base exchange process* makes use of the property possessed by certain mineral compounds of exchanging part of their constituent elements for other chemical elements in liquids with which they are brought into contact. Cases have been known where the beds of base-exchange materials in such plants have heavily contaminated water passing through them. This difficulty may be overcome by treatment with active chlorine during the brine-regeneration process on successive occasions.

There are various types of water-softening plant available for those contemplating the installation of such apparatus, but a detailed discussion of their merits or demerits is outside the scope of this volume. In choosing a water softening plant it should always be remembered that the treatment of water for commercial purposes is definitely a scientific process, and users, before deciding upon any particular type of equipment, should have the water it is intended to use analysed by a qualified chemist being guided in their choice of apparatus by a firm experienced in dealing with water-softening problems.

All water, steam and refrigeration pipes should be laid in tunnels under the various floors, this method being preferable to the normal system of suspension from walls or ceiling. The tunnels should be sufficiently large to allow the replacement or repair of pipes at any time without disturbing the floors.

The provision of a well-equipped *dairy laboratory* must not be overlooked and suitable accommodation should be available for the bacteriological and chemical control of milk both before and after treatment. In too many instances it will be found that the accommodation provided appears to be more in the nature of an afterthought, the laboratory being tucked away in some obscure corner of the premises and the scientific apparatus

OOD TECHNOLOGICAL RESEARCH IN

provided not only unsuitably housed but meagre in both quantit and quality. The provision of a laboratory in spacious quarter suitably staffed and fitted with all the necessary apparatu including a library of scientific works applicable to milk and it treatment, must be considered extremely important in th interests of the plant operator.

(2) **Layout.** If insufficient thought is given to the layout, th advantages to be obtained from a newly erected building or fro up-to-date machinery can be entirely nullified and, quite frequently, manufacturers of efficient plant fail to insist on rationa planning. An efficient layout should allow milk to flow forwar through each process in turn while there should be no change o direction in the flow either backwards or forwards. If this principle is observed, supervision is simplified, space economise and the length of pipe line reduced. Where the principle of heat exchange or regeneration is employed, the idea of "straight line" flow must be slightly modified. Good layout reduce labour and fuel costs, gives economy of space with a reduction o overhead charges, and provides room for expansion. The length of the various pipe lines can be considerably reduced if the layou is carefully planned and this will afford a considerable econom in running expenses. Care must, of course, be taken to ensur that economy in space does not cause the various components o the plant to become overcrowded, otherwise supervision an cleansing will be rendered difficult.

The essentials of a good layout are economy of space withou overcrowding, sufficient room for operation, cleansing, dismantling and for supervisory purposes, while temperature indicators should be placed so that they may be easily kept unde observation.

In many instances, an old or existing building can be satisfactorily employed for housing the apparatus if the layout i carefully planned. While this may be possible in certain circumstances, such adaptations should not be encouraged unless the proposed changes will ensure a satisfactory layout with sufficien room for expansion.

The method of arrangment naturally depends upon the typ of apparatus to be installed and certain factors must be considere before any plant is provided. The size of the plant require primarily depends upon the quantity of milk to be handled daily although before a final decision is actually made, due consideration must be given to any probable increase in the quantity of to be handled. Milk may be treated in one batch, in morning or evening batches or even in three or four batches or more per day. Upon the system of treatment employed and the continuity of such treatment depends the size of the plant required. The needs of the small distributor would probably be adequately met by the employment of one or two " Batch " holders, whereas a large operator would naturally need something more elaborate. The type of cooling employed has a bearing upon the question. In this connection it should be remembered that persons using " Batch " pasteurisers may, if they so desire, supply a primary cooling to the milk while it is still in the holder, although this method cannot be recommended. The manner in which the apparatus is installed must be considered. It may be found more convenient to employ two small holders in place of one large tank and this depends entirely upon the space available. It should be remembered also that it is more economical to carry out all processing operations at one level. If the operator wishes to produce milk which is to be sold as " Pasteurised " under licence from the local authority, it will be necessary to install an approved low-temperature plant or short-time apparatus. For commercial pasteurisation, with a desire to improve keeping quality only, any type of plant suitable for this purpose may be employed, according to the space available. The operator should, however, bear in mind the fact that pasteurisation may eventually be made compulsory, and that such apparatus may not satisfy the requirements of the licensing authority.

(3) **Plant.** Before consideration is given to the various components of the modern plant, mention must be made of certain prime essentials. All parts of the apparatus should be constructed of highest quality metal, excepting, of course, the specially prepared rubber jointing material necessary to provide milk- or water-tightness. Permanent joints or seams can be assured by employing autogenous welding, the use of solder being likely to produce electro-chemical action. The provision of reliable temperature indicating and recording instruments, as will be mentioned in more detail at a later stage, is essential, while preferably the plant should be automatic in action, milk being untouched by hand from beginning to end of processing.

This applies principally to large plants but is preferable for Sufficient capacity to treat all milk passing through without a need for accelerating processing to the detriment of the fi product should be provided. As already indicated, fut expansion of business must receive consideration when a decis regarding the capacity of the plant is made. All appara

SCHEME OF PASTEURISING PLANT.[1]

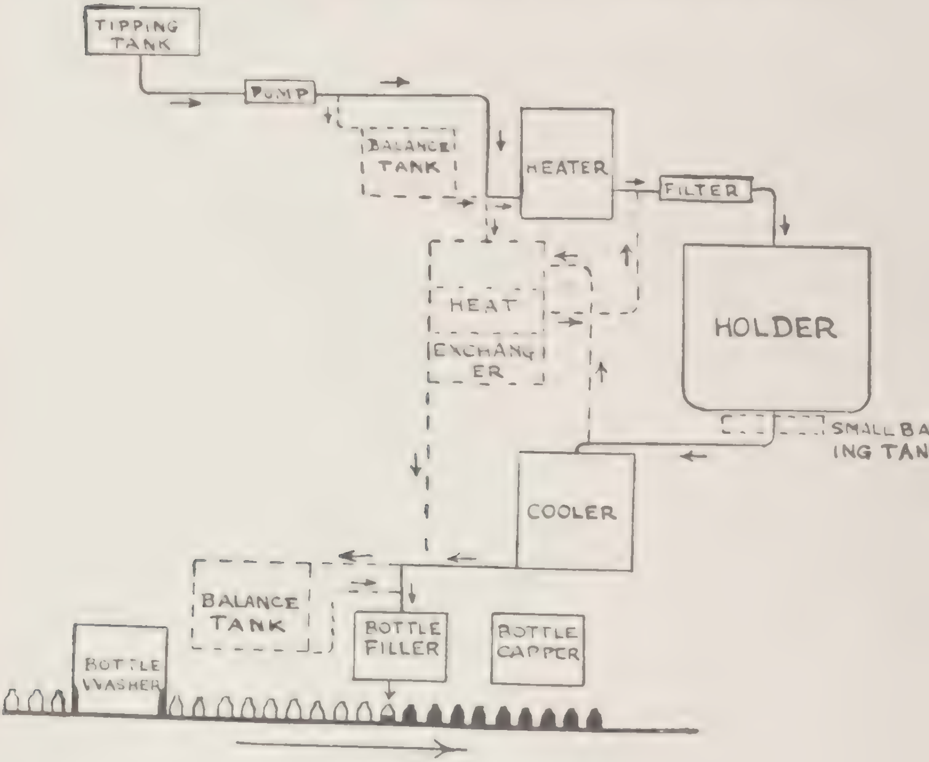

Fig. 1.

must be designed so that cleansing and sterilisation are simplifi Corners and angles must be avoided while bends in pipe-li should be reduced to a minimum and given as large a radius possible in order to avoid harbourage of dirt or bacteria and accumulation of milk-stone.

The whole equipment requires to be thoroughly co-ordinat and not be merely an assortment or grouping of a number of different machines. The entire plant must be envisaged as a single unit, the choice and arrangement of the various pieces of apparatus conforming to this principle.

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[1] Reproduced by permission of the Controller of His Majesty's Station Office from Reports on Public Health and Medical Subjects, No. 77, of Ministry of Health—"The Supervision of Milk Pasteurising Plants," 1935.

In short, pasteurising plants should be inexpensive to maintain, reliable, efficient, simple in construction and compact. They should be constructed of durable materials, easily operated and kept clean, and be continuous in action. Simplicity of arrangement with economy of space should be the keynote.

The complete plant for the pasteurisation of milk consists of a number of component parts, each of which requires detailed consideration.

(i) TIPPING OR WEIGH TANKS. Tipping tanks are usually required in the majority of dairies, and these are generally placed on the receiving platform in a position which renders the milk liable to contamination with dust and dirt from the open yard of the premises. These tanks may be arranged in two ways according to the owners' requirements. They are sometimes installed above the level of the floor with the top of the tank slightly above the conveyor which carries the incoming churns, so that no lifting is required. In other premises they are placed slightly below floor level, the incoming churns being pushed across the floor and emptied on the same level. Metal splash hoods and removable covers, which can be raised as necessary, are required to afford protection to both the tanks and their contents from air-borne contamination and to prevent any oil droppings from the machinery entering the milk. Coarse strainers, composed of wire gauze or other filtering media, designed to remove the larger particles of extraneous matter such as straw, hairs and particles of dung are essential, while can drainage racks, if provided, should be easily detachable for cleansing purposes. In some cases, these tanks are fitted with agitators in order to secure homogenity in milk passing through and such apparatus should be constructed so that there will be no interference with cleansing operations. These tanks must not be regarded as essential, but in the majority of cases their employment is necessary. They usually serve the dual purpose of receiving and weigh tanks, so that a check may be kept on the quantity of milk received from individual producers. Weigh tanks may possess one or two compartments, the latter type saving time in handling,

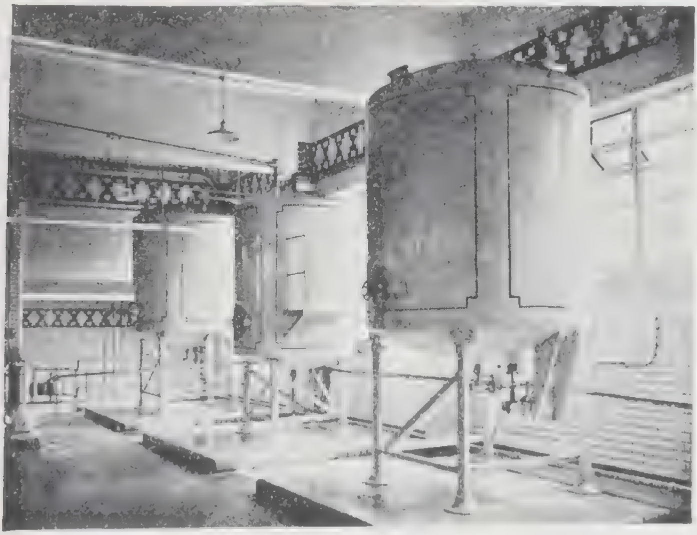
especially when milk is received from a large number of farms
In many small plants, the milk is weighed in the churn on scale
whose adjustment requires to be periodically checked. Supplie
received in road or rail tank wagons are usually pumped direc
to storage tanks. Tipping tanks should be constructed for pre
ference of stainless or chrome nickel steels as these metals are re
sistant to the corrosive action of milk while their surfaces ar
easily cleansed.

(ii) PUMPS. Where tipping tanks are provided at ground leve
pumps are usually required to raise the milk to storage tank
situated at a point from whence it may gravitate throughou
the plant or to propel the liquid to the preheater. The rotar
pump is to be preferred for this purpose as this type causes les
damage to the milk and ensures a uniform flow. Other adva
tages are simplicity of construction and high efficiency. Centr
fugal and valveless pumps are also employed, each type possessin
its own characteristics. Centrifugal pumps are usually employe
when milk is to be transferred to equipment on the same floo
level and with gravity feed, the pump being kept full of milk an
foam formation prevented. They provide a steady, non pulsatin
flow, are simply constructed and can be directly connected to a
electric motor. Their output is usually regulated by a valve i
the discharge line. When the vacuum and compressed-air syste
of operation is employed, pumps are not usually necessar
If desired, the function of a pump may be performed by a cen
trifugal clarifier which can be used to withdraw milk from the tip
ping tank. The choice of the pumps installed is important, a
otherwise milk may become grossly contaminated and it i
essential that no glands or stuffing boxes should come into contac
with the liquid. They should be constructed of stainless steel i
order to prevent any possibility of metallic contaminatio
while the design of the plant should, if possible, render thei
employment unnecessary.

Pumps which are badly designed are one of the most seriou
causes of frothing or foaming. Foaming interferes with th
efficient treatment of milk, and, in addition, damage to crea
line will occur. Pumping should be reduced to a minimum and th
operation where necessary should be carried out if possible whe
milk is in a warm condition. Cold milk should not be agitate
or pumped at temperatures below 125° F. more than is essentia

in order that the cream-line may be preserved. A plant in which it is necessary to pump milk after cooling is badly planned. In the design of plant, therefore, arrangements must be made to ensure that all essential pumping is carried out prior to holding while the milk is warm.

(iii) Receiving or Storage Tanks. As it is the practice in many dairies to store milk until required for use in order to avoid any interruption in processing, large-capacity, insulated receiving tanks are usually installed, all milk being cooled before it is allowed to pass for storage. Such tanks should be constructed of stainless or chrome nickel steels, or provided with glass-enamelled internal surfaces. These materials facilitate cleansing and it is necessary that the tanks should be provided with suitable means of access for this purpose. Where gravity flow is employed, the tanks are installed above the remaining apparatus, usually near the roof of the premises, but if the vacuum-and-compressed-air system is provided, they may be fitted on the same level as the other component parts of the plant. Some form of agitation is necessary, but the agitating gear must be well-designed, otherwise cleansing will be rendered difficult.



By courtesy of Enamelled Metal Products Corporation (1933), *Ltd.*

Fig. 2. "Pfaudler" glass-lined steel milk storage tanks.

Tanks for receiving milk as it leaves the holder compartments are often installed. These are usually termed "*balancing tanks*," their purpose being to equalise the milk before it passes to the cooling and bottling apparatus. While such tanks are most undesirable, they should, if provided, be fitted with suitable covers and any foam which occurs should not be able to find its way back from the cover into the milk. "Balancing tanks" may be employed for storing cooled milk after pasteurisation to ensure that the bottle filling machines can be kept constantly running This practice cannot be considered satisfactory as plant should be designed so that the process of heating, holding, cooling and bottle filling are continuous. Agitation of the liquid in these tanks is said to reduce the cream-line by as much as 10 per cent of the total volume.

(iv) Preheater. The process of preheating, which is equally as important as the subsequent cooling, is often termed "pasteurisation" by those in charge of the plant. It is a very important process as, at this stage, the need for precision working commences. The preheater should deliver *all* milk to the holders a a temperature above the legal minimum but below the lega maximum, this being usually between 1° and 2° F. above th minimum required. This higher temperature is necessary on account of the slight loss of heat which is liable to occur during the passage of milk through the pipe lines and filter to the holding compartments, and, during the time it is held in the latter vessels In small plants of the "Batch" type, preheating and holding ar often carried out in one vessel, but this practice cannot be considered satisfactory, temperature control being more difficul than is the case when preheaters and holders are entirely separated. It will be readily understood that badly designed heaters will cause uneven heating of milk. There are five mai essentials if the preheating system is to be entirely satisfactory Primarily, all milk must be raised to a temperature somewha above the legal minimum but below the legal maximum. Th complete separation of the raw from the treated milk and from the heating agent is essential, while the milk should be protected from contact with the atmosphere. Finally, the apparatus should be easy to cleanse and sterilise.

Before considering the various types of preheaters employed certain basic principles with regard to efficiency require to b noted. These are :—

(*a*) Metals employed in construction must be good conductor of heat.

(*b*) Metals should be fabricated as thinly as possible consistent with proper mechanical strength.

(*c*) Temperature differences between the liquid and the heating medium should be as great as possible always provided that accurate temperature control can be achieved and that no deleterious effect is exerted upon the liquid being heated.

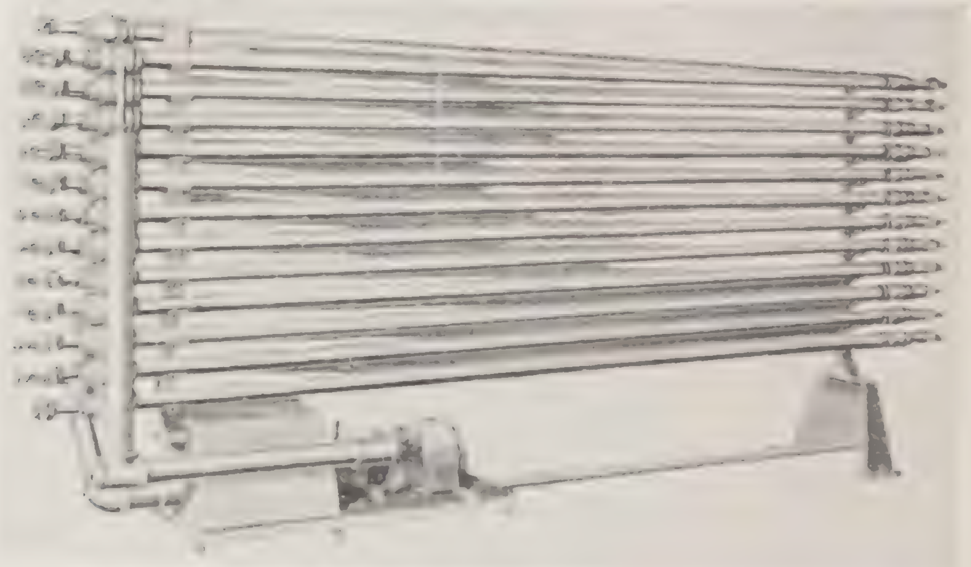
(*d*) It is essential that the liquids should flow rapidly on both sides of the heat-transfer surface.

(*e*) The degree of agitation of the liquid must be strictly controlled although agitation assists in the quick transference of heat.

There are many types of preheaters for which specific advantages are claimed. One type is an apparatus similar to an ordinary surface cooler, hot water running through the interior of the tubes and milk passing over the outer surface. The employment of this type has nothing to recommend it as it possesses all the disadvantages of the surface cooler in so far as contamination of milk from the atmosphere is concerned, while the surfaces of the tubes are difficult to efficiently cleanse and sterilise. It is, however, relatively inexpensive while rapid heat transfer is obtained. When this type of apparatus is employed, particular attention must be paid to the joints where the tubes enter the tube plates, as a failure at this point would be followed by re-contamination of the milk. While this apparatus is extremely flexible, its operation must be carefully controlled. The surface will not be properly covered if the flow is too slow ; if too fast the milk will splash off the heating surface.

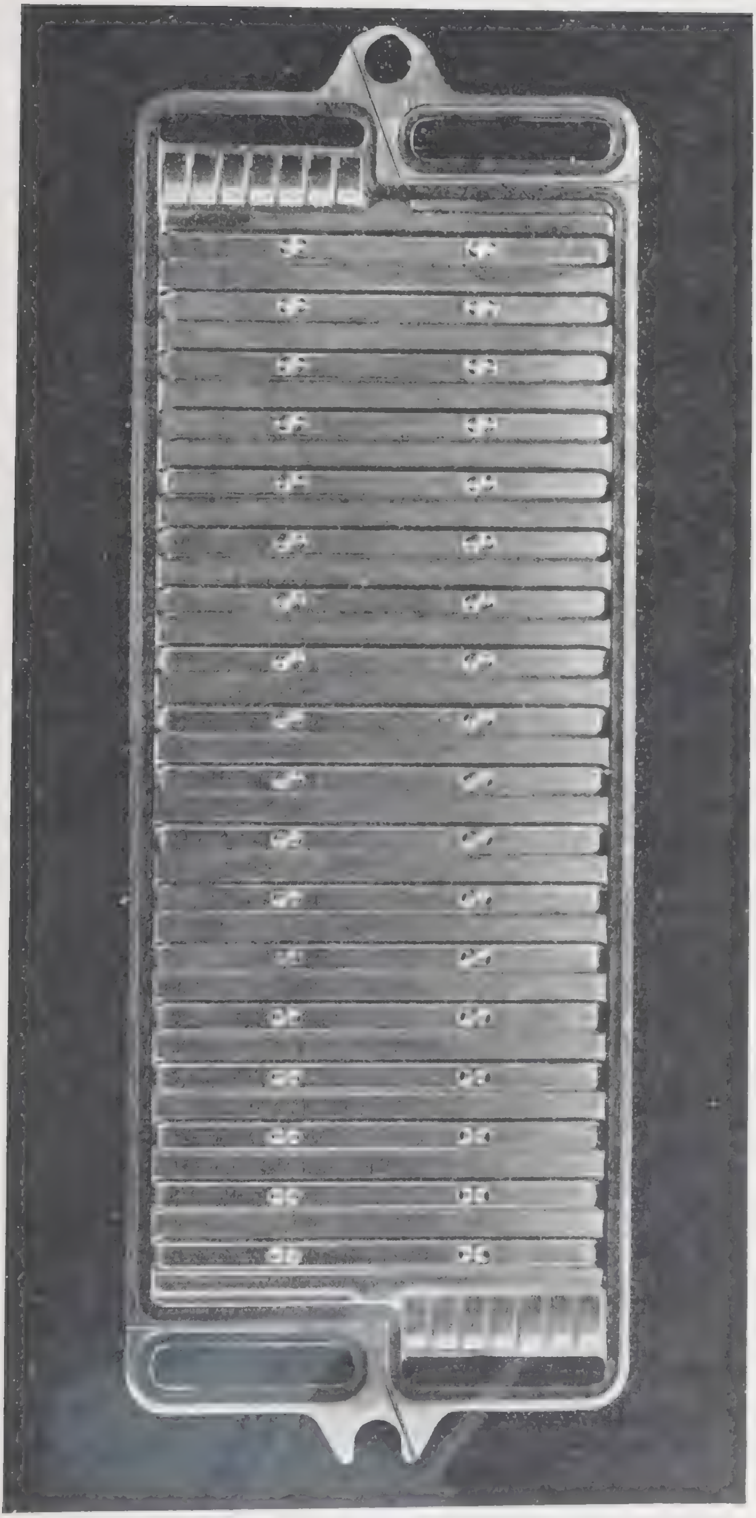
Another apparatus is designed to revolve milk rapidly round the heated inner surface of a conical vessel, the liquid being thrown by centrifugal force over the upper edge of the cone. The time taken for the milk to rise from the base of the cone, to which position it is constantly fed, until thrown over the upper lip, is said to be sufficient to raise the temperature to the desired level, but there is no guarantee that this is so. This type of apparatus usually causes foam formation.

A tubular type of preheater is frequently employed in which milk passes through tubes surrounded with hot water which acts as the heating agent and its employment prevents overheating which is likely to occur when steam is used for this purpose. The *tubular heater*, one of the two most common types found in this country, consists of a series of double tubes, suitably interconnected, together with a water circulating pump and temperature controller. The tubes are arranged in sections, each usually from 10 to 14 feet in length. The milk to be heated flows through the centre tube, while the heating agent circulates through the larger outer tube. The area of the heating surface must be sufficient to heat the milk without the employment of excessive water temperatures, otherwise a cooked flavour will be imparted to the liquid. The water circulated should be in high ratio to the milk to be treated. In the regenerative types of tubular heater, hot water is employed in addition to hot milk as the heating agent. A separate cooler may be provided although regeneration with brine cooling may be employed if desired, this being the most common practice. Tubular heaters are very satisfactory and give good results, while the milk is not exposed to the atmosphere and there is no loss through evaporation. One point requires to be noted by potential users of this type of apparatus. A fair



By courtesy of Cherry-Burrell, Ltd.

FIG. 3. "Uniflex" tubular heater.



By courtesy of the Aluminium Plant and Vessel Co., Ltd.

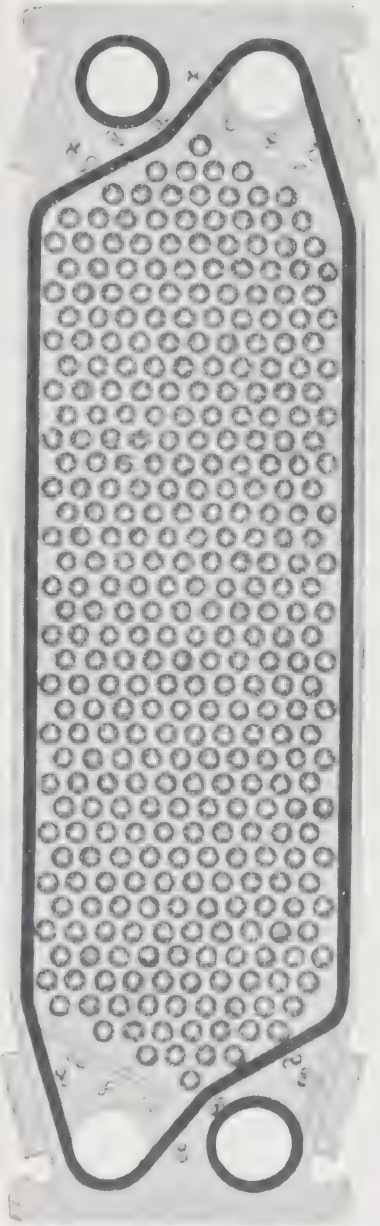
Fig. 4. A.P.V. heat-exchanger plate.

amount of room is required for their installation owing to the length of the tubes, extra space being necessary to allow for their withdrawal for cleansing. Extra time and care are required for cleansing this type of apparatus, while the maintenance of the joints sometimes presents a certain amount of difficulty. Additional special sections can be employed for final heating and cooling and the only manner in which the milk may become contaminated is by the perforation of one of the tubes.

It is now the accepted practice to combine the preheater and cooler and to apply the principle of "heat exchange" or "regeneration" as it is often termed, in which hot, pasteurised milk passing through the apparatus gives up its heat to cold milk moving forward for treatment. Although further heating and cooling are required, in this way it is possible to effect great economies in fuel costs.

Several types of apparatus are used for this purpose. The simplest is a modified form of ordinary *surface cooler*, the milk to be cooled passing over the external surface, while the liquid requiring to be heated passes through the interior of the apparatus. This cooler possesses all the disadvantages of its type as regards contamination from the atmosphere, while it is almost impossible to cleanse and sterilise efficiently the internal surfaces of the tubes. Another type is the *double-tube heat-exchanger*, similar to that illustrated in Fig. 3, but consisting of a series of concentric tubes suitably interconnected. The milk to be heated flows through the annular space provided between two concentric tubes, while that to be cooled flows through the inner tubes. This type of heat-exchanger will give satisfactory results and the milk is not exposed to the atmosphere. Both these types require the addition of further sections for final heating and cooling of milk.

The *plate heat-exchanger*, originated in this country in 1923, is probably paramount as a regenerative apparatus. It consists of a series of flat, grooved tinned gunmetal or stainless steel plates which are clamped tightly together so that the grooves form a series of channels. In some types the plates are provided with "knobs" or other irregular surfaces instead of grooves, while metal cones are sometimes substituted for plates in certain apparatus of this kind. The milk to be heated (or cooled) flows along one side of the plates, while the heating (or cooling) agent, usually hot water (or cold or brine-cooled water), or hot milk passing to the cooler, flows along the other side. By this means the liquids exchange heat and on account of the long shallow nature of the grooves, this heat exchange is extremely rapid. The plates are fixed about ¼ inch apart, their corrugations forming troughs which, when they are clamped together and the machine is closed and ready for use, form a series of channels through which the milk flows. The design of the plates causes the milk to be retarded at frequent intervals and this retardation produces a pulsating flow or turbulence which assists in the quick transference of heat and gives economy of working. The plates are rapidly uncoupled for cleansing purposes.

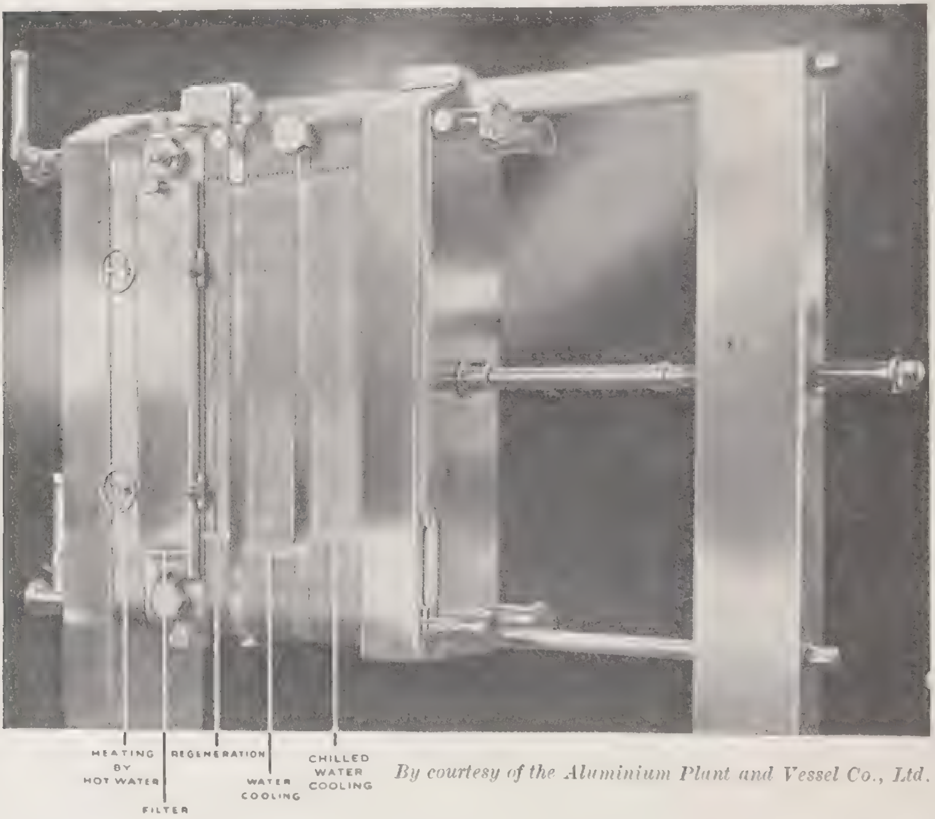


By courtesy of Cherry-Burrell, Ltd.

Fig. 5. Cherry-Burrell heat-exchanger plate.

It is important to remember that the flow of milk through the apparatus should remain constant and the plant should run at its rated speed per hour. It is not advisable to restrict the flow of liquid at any time as if fluctuations occur both bacteriological and mechanical troubles will ensue. The apparatus usually comprises four sections. The first is the regenerative section in which incoming cold milk is given a preliminary heating by hot milk leaving the holder. After this treatment it usually passes through the filter from where it is returned to the preheating section in which the warm filtered milk is given a further heating by means of hot water which raises the temperature to between 146° and 147° F., or to 162° F. according to the method of processing employed. The milk then travels to the pasteuriser and after the requisite period of time has elapsed, it returns to the regenerative section to receive its primary cooling. From here, it enters the water-cooling section which supplies a secondary cooling and finally passes to the brine-cooling portion of the apparatus where its final temperature is reduced to 40° F. or less.

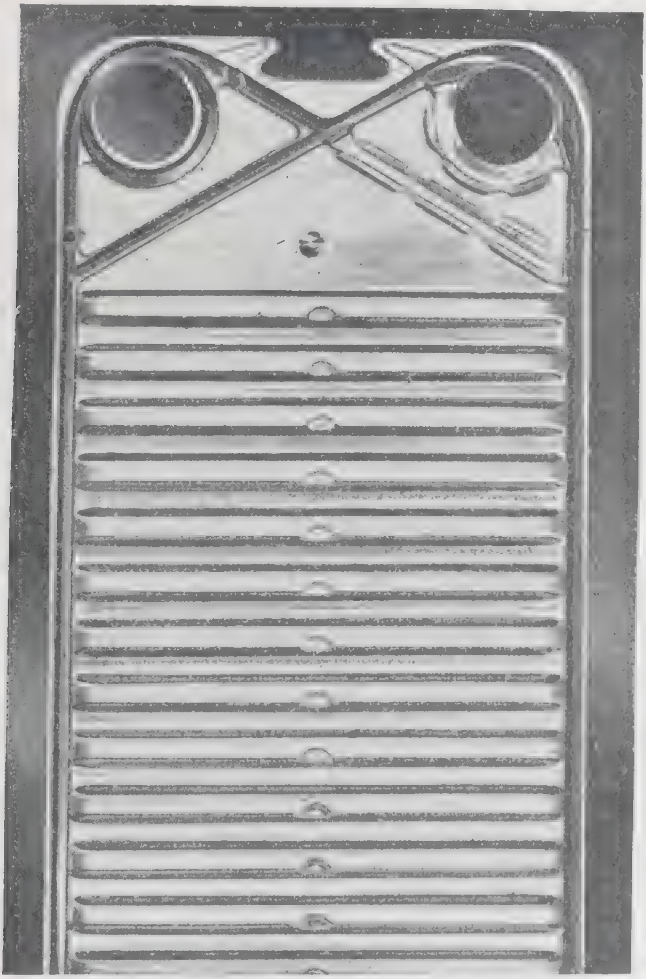
With this type of apparatus, milk can only become contaminated should a plate become perforated. It is easily cleanse and possesses the advantage of compactness, while its capacity can be increased or reduced to any given volume according t the number of plates employed. The heating agent is normally hot water so that it is not possible for the milk to become overheated.



By courtesy of the Aluminium Plant and Vessel Co., Ltd.

Fig. 6. A.P.V. "Paraflow" plate heat-exchanger.

Several advantages are claimed for the plate type of apparatus. Milk is not brought into contact with any steam-heated surfaces since the heating, when not carried out by the treated milk, is attained by water only a few degrees higher in temperature than the milk itself. There is no contact with air, thus avoiding contamination and oxidation together with a complete absence of foaming. The apparatus is easily examined, cleansed with an ordinary brush and sterilised by means of steam, while no losses through evaporation take place such as are experienced when hot milk is passed over an open cooler. This may often amount to 1 per cent. of the total milk treated. A saving of 50 per cent. in the steam normally required is secured together with great

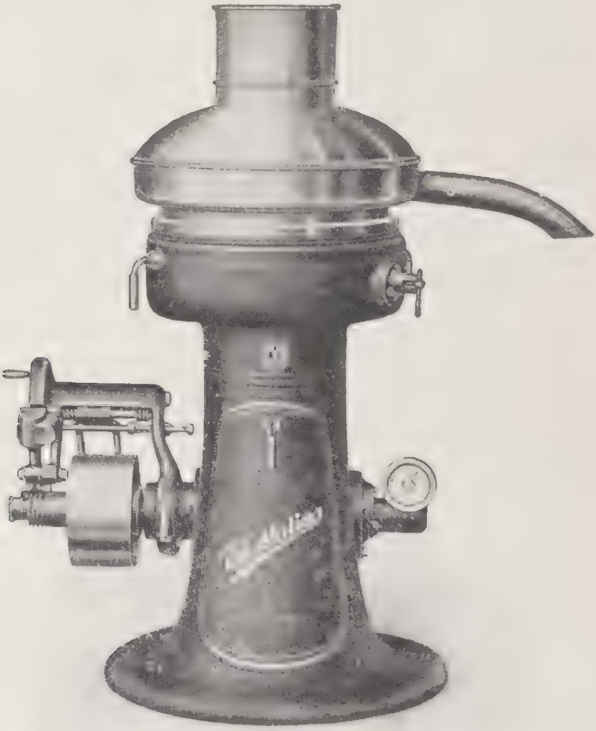


By courtesy of the Aluminium Plant and Vessel Co., Ltd.

FIG. 7. A.P.V. "Paraflow" heat-exchanger plate.

economy of floor space even when carrying out the operation of heating and cooling up to 6,000 gallons of milk per hour.

The principle of heat exchange in plate heaters already outlined has been carried a stage further in the *A.P.V. Paraflow* apparatus shown in Fig. 6, and the rate at which heat is transferred per square foot of plate area has been increased so that a smaller plate is required than was formerly necessary.

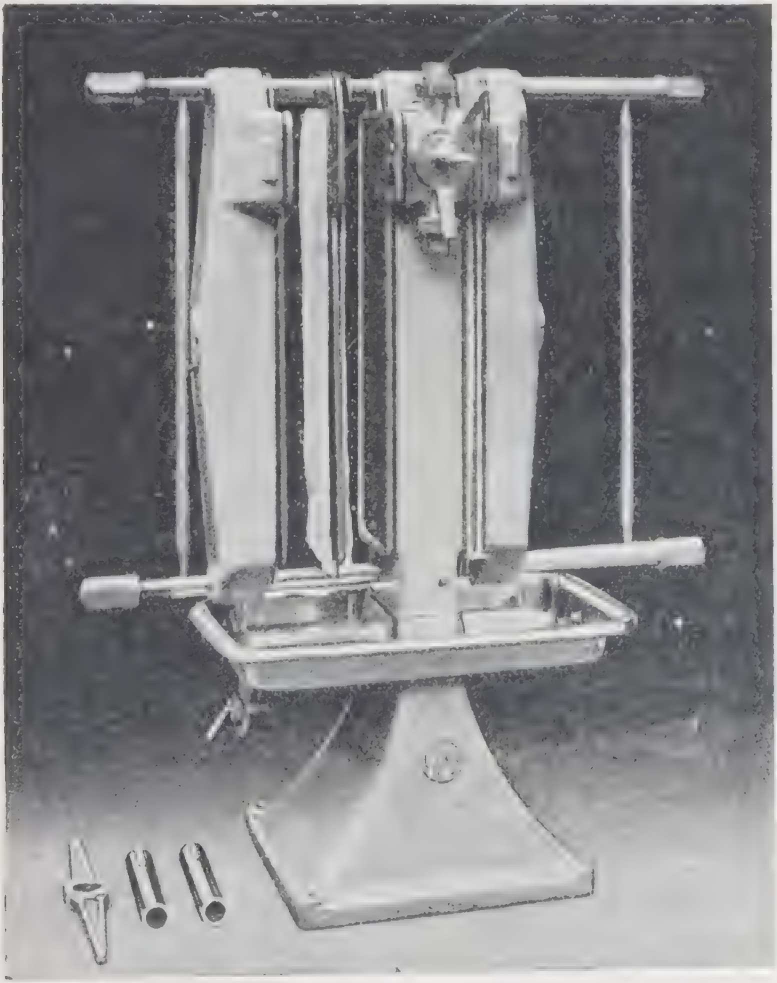


By courtesy of the Dairy Outfit Co., Ltd.

FIG. 8. Power clarifier.

When compared with the older type of apparatus, a saving of 30 to 35 per cent. is possible as regards plate sizes without any necessity for increasing the working pressure. This also permits a high degree of heat regeneration with a consequent saving in the amount of heat required for pasteurisation and also in the time required for cleansing. Fig. 7 shows a portion of one of the stainless-steel plates which differs from that illustrated in Fig. 4 as will be noted when the two illustrations are compared. A clearer milk passage with improved distribution is provided. The apparatus contains a built-in filter (see Fig. 12), which can handle up to 2,000 gallons of milk per hour, as against 1,500 gallons per hour which has hitherto been the normal maximum.

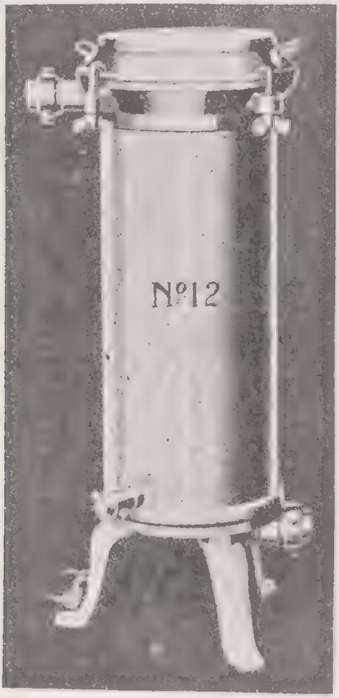
It is essential that a recording thermometer should be fitted in addition to the normal type of indicating thermometer at the outlet from the heater to the holders, in order to ensure that all milk passing forward is raised to the necessary temperature. A fall in temperature at this point, which may amount to two or three degrees, can be detected easily and if very near to the minimum required, a careful check of the pasteurised milk temperature should be made.



By courtesy of the Aluminium Plant and Vessel Co., Ltd

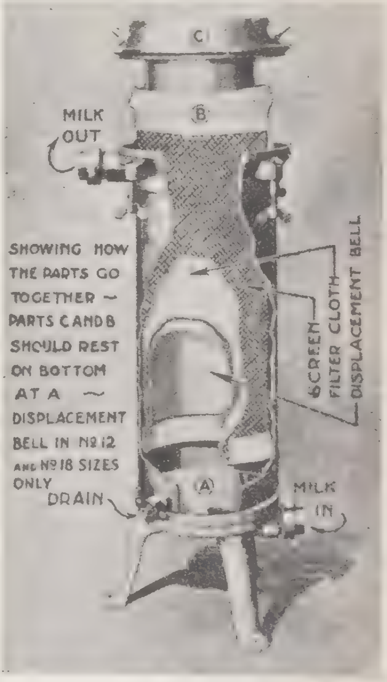
FIG. 9. A.P.V. continuous filter (opened for cleansing).

(v) Filters. The filtration or clarification of milk is necessary for the removal of dirt and slime, although it must be understood that neither process affects the bacterial content. Filters are generally fitted between the preheater and the holding sections, the milk passing through them after the first stage of heating to a temperature of approximately 90° F. is completed. Warm milk can be filtered much more easily than cold, with less disturbance to the cream-line. Filtration after preheating tends to cause loss of heat, but this is not important when the enclosed, hot-water jacketed filter is employed.



By courtesy of Cherry-Burrell Ltd.

Fig. 10. Bag filter.

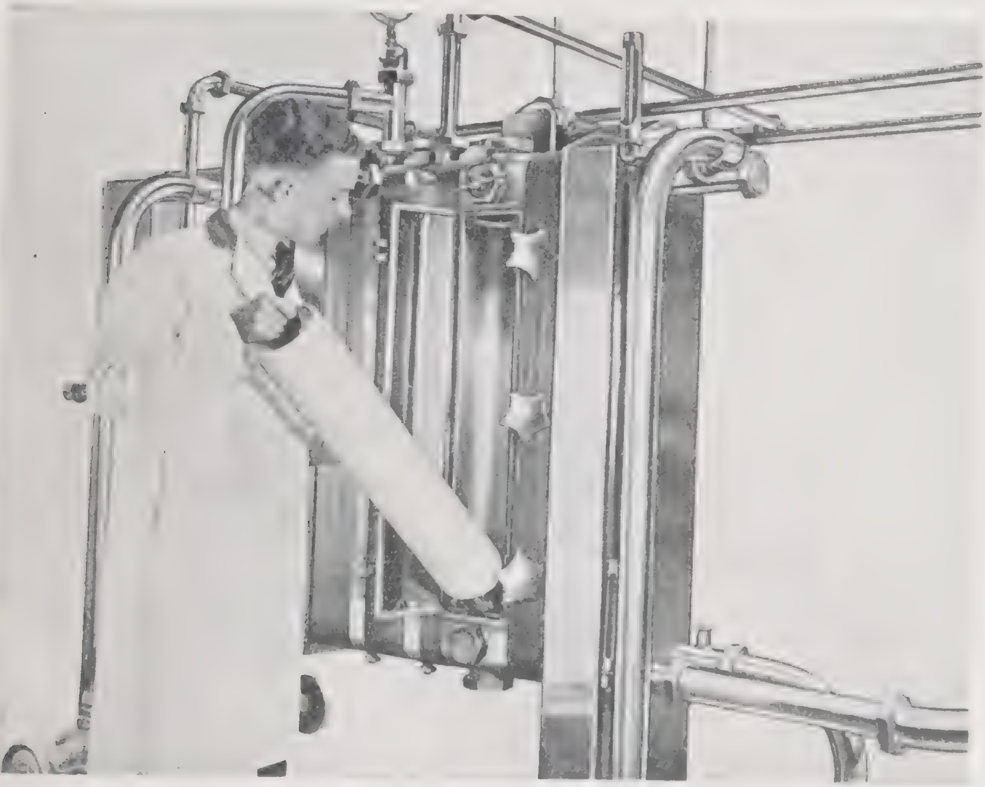

C
B
MILK OUT
SHOWING HOW THE PARTS GO TOGETHER — PARTS C AND B SHOULD REST ON BOTTOM AT A — DISPLACEMENT BELL IN Nº 12 AND Nº 18 SIZES ONLY
SCREEN
FILTER CLOTH
DISPLACEMENT BELL
DRAIN
(A)
MILK IN

By courtesy of Cherry-Burrell Ltd.

Fig. 11. Bag filter (section).

Some distributors make use of a centrifugal milk *clarifier* which combines the functions of heater, cleaner and milk pump. These machines work on the principle of a cream separator, extracting visible dirt, epithelial cells and slime by means of centrifugal force. They operate very efficiently at 2,000 revolutions per minute if milk is preheated, but their churning action tends to alter the texture of the liquid and causes the formation of foam. The effect on the cream-line varies according to temperature.

being little altered in this respect at temperatures under 40° F., but being definitely affected at 100° F. and over. On this account, these machines are gradually being replaced by cloth filters. When employed to assist in maintaining the milk temperature they are always fixed between the heater and the holders similarly to cloth filters, but if used for cleansing purposes only, are generally fixed in front of the heater.



By courtesy of the Aluminium Plant and Vessel Co. Ltd.

ɪɢ. 12. A.P.V. "Paraflow" heat-exchanger showing one unit of the Duplex filter.

Filters should be of the *enclosed* type, arranged so that the filtering medium can be changed without interruption of the process. Enclosed filters lend themselves admirably to the "closed circuit" method of operation now so popular as this method ensures that milk at all stages of processing is not in contact with the atmosphere, thus preventing any risk of air-borne contamination. The apparatus should be provided with a hot-water jacket in order that the temperature of milk passing through may be maintained at the requisite level. Filters should be constructed so that they are easy to dismantle and arranged so as to prevent any unfiltered milk passing through or any waste when the filtering medium is changed. Cotton cloth which possesses one "fluffy" side is employed for filtration purposes, being supported by some form of metal disc or cylinder. In practice, care must be taken to ensure that the milk pressure does not exceed 10 to 12 lbs. per square inch or the fabric may tear, resulting in improper filtration. This pressure is sometimes increased when slow filtration, due to chokage or insufficient surface area, is experienced or when attempts are being made to filter cold milk. The "fluffy" side of the cloth should be placed so that it faces the flow of liquid. The fluff is driven into the cloth as milk passes through and effects filtration. Cloth filters are quite as efficient as clarifiers, require no power to drive them and cause no interference with the texture of milk or alter its cream-line.

In some plants, the filter is of the enclosed cylindrical type, the filtering bag being a stockinette type of cloth of from 40 to 90 mesh. The modern, continuous built-in filter illustrated in Fig. 12, is of the cylindrical type, and while it allows the filtering medium to be changed without any interruption of processing, the incorporation of the apparatus in the heat-exchanger in the manner shown saves floor space and, by reducing pipe-lines, simplifies the lay-out of the plant. This type of filter will handle up to 2,000 gallons of milk per hour.

Filter cloths and other filtering media require to be changed several times during processing operations. A supply of sterile cloths should be readily available, stored in a protected container. Some large plants use a number of filters in order to prevent delay in treatment when cloths are being changed. Filtering material should be employed once only, after which it can be washed, dried and used for cleansing purposes.

(vi) HOLDERS. The holding section is the most important portion of the plant as here milk should be treated in accordance with the statutory requirements as to time and temperature. Accurate working is essential as these requirements must be strictly adhered to if the process is to be efficient from a public health point of view and a commercial success. This portion of the plant is most vital, as upon the success of milk treatment at this point depends the safety of the entire method. Detailed consideration is required owing to a number of difficulties which may arise in operation and a proper understanding of design and construction is essential.

Apart from the retarding sections of short-time apparatus mentioned in Chapter VIII, holders vary in design from the single compartment "Batch" pasteuriser to a series of compartments or tanks provided for the plants installed by large operators. It is essential that each compartment should possess a separate milk inlet and outlet. There should be complete separation of the various compartments both during the holding period and during inflow and outflow, whilst any chance of overflow from one compartment to another must be carefully guarded against. Each compartment must be covered to protect milk from contamination during treatment, to prevent heat losses and the oxidation of the liquid, and covers should be designed so as to prevent the formation of any milk pools upon their upper surfaces.

Milk preheated to the required level enters the holder and this temperature must be maintained and the milk held for exactly 30 minutes before it is discharged. Accurate working of the holder or its several compartments is essential, and must be strictly observed if processing is to be efficient; this requirement cannot be too often emphasised.

To fill or discharge the holder, its various compartments or the separate holding tanks, some type of hand- or mechanically-operated valves are necessary except, of course, where the vacuum system of operation is installed. Mechanical operations for this purpose are to be recommended and, where provided, the system should be controlled by means of automatic timing. Automatic control is always to be preferred to hand operation as any carelessness on the part of employees is thereby obviated. This type of control must be foolproof and its accuracy should be periodically checked as no mechanical device, however perfect, can be relied upon to remain accurate for all time. In large plants, the complete cycle of filling, holding and discharging usually occupies 45 to 60 minutes, the time varying according to the number of compartments employed. An interval of 7½ to 15 minutes is usually allowed for each compartment to fill and discharge.

When the *vacuum-and-compressed-air system* is employed, the problems of valve operation do not arise, but it is particularly important to ensure that the air supply to the compressor is filtered. This system has become popular on account of the development of the "closed circuit" method of operation. Milk, instead of being pumped or falling by gravity throughout the system, is carried by means of a vacuum to the various compartments and is expelled from these through the cooling system by means of compressed air. The charging main is under vacuum, the holder at atmospheric pressure, while the discharging main is under positive pressure. The flow of milk is not governed directly, but an *electrical timing mechanism* controls the application of the vacuum and compressed air to each tank in turn so that no milk can enter or leave until air pressure is applied. This system renders the holding process independent of valves, simplifies control and allows the entire process to be carried out free from air-borne contamination. The system operates on one floor without the employment of pumps, while from heating to bottling, the milk flows naturally and, as the pumping of cold milk affects the cream-line, this is important.

During the entire process the milk remains in a closed circuit with no exposure to the atmosphere, oxidation and evaporation being therefore eliminated. The entire operation is performed automatically, labour charges are reduced and the liquid passes through no cocks or valves, which require to be set either automatically or by hand. It should be emphasised that nothing moves except the milk while the process is always positive.

When one holder has been filled, the vacuum is transferred to other tanks alternately, these being filled in strict rotation. Each tank is allowed to remain full for the pre-determined period of 30 minutes and, when this time has elapsed, each is discharged by means of compressed air which has been previously washed and filtered and which drives the milk from the tanks. When the tanks are being filled, the hot milk is under reduced pressure which facilitates the escape of any "off" odours. The capacity of this type of plant varies from 400 to 6,000 gallons of milk per hour.

In some plants employing this system, the tanks are grouped together within a common framework, being filled from the base and emptied from the top, the milk discharging upwards through a standpipe. The only leakage which can take place is backwards, from milk which has been treated into that which is undergoing treatment. It is essential that the reservoir from which the raw milk is drawn should be placed at a lower level than that of the holding compartments, in order to prevent milk flowing into the tanks during processing.

The method of feeding the milk into the several compartments of the holder is important. Methods of filling vary, milk being either fed from the upper or lower portions of the compartments, and being discharged in a similar manner. The method employed depends to a very great extent upon the methods of valve timing in use, but if milk enters at the upper end, the inlet pipe should be carried to the base of the tank to prevent foam formation, which may form a continuous blanket over the surface of the milk being processed. In a well-designed plant, foaming should be impossible. This is particularly important as the foam temperature may be anything from 8° to 15° F. below the requisite pasteurisation temperature, while the milk receives extra exposure to the atmosphere, favouring the destruction of certain vitamins due to oxidation and impairing the flavour of the milk. Plant design should ensure that the foam which is present on the surface of the milk when in the holder should be maintained at correct pasteurising temperature. The manner in which such temperature maintenance can be carried out is dealt with on p. 75. While outlet valves are usually provided at the lower end of the holder compartments, they may be placed above if desired, always provided that the compartments are designed to ensure complete exhaustion of the milk. When the outlet valves are placed above the holder, the same mechanical timing gear for both inlet and outlet valves can be employed and such gearing is more accessible for adjustment when placed in this position.

Valve design is of considerable importance, inefficient valves allowing leakage of partly-treated milk and causing the final product to be unsatisfactory. It is particularly important that there should be no forward leakage in order that "unheld" milk cannot obtain access to that which has been treated. Generally, it is impossible for milk to leak backwards, but, if this occurs, it is comparatively unimportant provided such liquid runs to waste and is not able to return for re-pasteurisation in direct contravention of statutory requirements.

Valves and their gearing must always be precision instruments, the valves opening and closing to a pre-arranged schedule.

With standard A.C. current, valve-operating gear can be controlled with extreme accuracy. As all types of timing systems require to be accurate, it is necessary to emphasise again that this accuracy requires periodical checking. Valves should be constructed of stainless steel, no glands or stuffing boxes coming into contact with the milk. Valve seatings are generally metal to metal, but if packing is required, care should be taken to ensure that this provides no harbourage for bacteria. There should be no connection between inlet and outlet pipe-lines and the inlet valve of one compartment should never feed the inlet valve of another, owing to wear on the seatings. Valve wear is enhanced by the corrosive action of the milk passing through and by scoring or damaging the ground faces by the careless handling of the persons employed. With some types of plant, milk may be re-contaminated through unsatisfactory valve design. Flush-seating valves should always be provided, the valve seat being built into the valve so that it lies flush with the inner surface of the holder compartment and no pocket is formed in which sub-temperature milk may be retained. Valve seatings should be inspected periodically to ensure tightness and freedom from drips and care should be taken to make sure that any such drips from inlet valves do not come into contact with the treated milk but run to waste.

It is necessary to maintain the heat of all milk entering the holder for the specified period of 30 minutes and also to prevent any drop in temperature during that time, irrespective of whether or not it has been preheated prior to entering the vessel, or whether it still requires to be heated. The difficulties which arise from the likelihood of temperature drop are overcome in a variety of ways, all types of plant making some provision for heat-maintenance. In some instances, the water contained in the jacket surrounding the holder is heated before the milk enters. No further heating is attempted, the jacket remaining filled with hot water during the entire holding period. The water temperature naturally drops and in order to compensate for this heat loss, either the temperature of the milk is raised to the maximum allowed, or the water temperature is maintained at a considerably higher level than that required for processing. It will be readily understood that this method of heat maintenance is crude and extremely objectionable on account of the damage which may occur to milk, particularly to its cream line and nutritive value, through over-heating. Further, there is no guarantee that the liquid will remain at the desired temperature for a 30-minute period. With other designs, hot water is employed as the heating medium, thermostatic control ensuring efficient heat maintenance by allowing the injection of steam. When this method is adopted, it is necessary to supply a generous quantity of hot water to ensure that the interchange of heat is complete.

A common method of heat maintenance is provided by the complete insulation of the holder or its compartments either by means of air, by creating a vacuum in the jacket surrounding the tanks, or by means of cork, asbestos lagging or plastics. Insulation, whatever type is employed, must be highly efficient if it is to be satisfactory and there is no doubt that some loss of heat does occur although many manufacturers claim great success with such methods. If lagging is employed, efficiency depends entirely upon the material used and the manner in which such material is packed around the vessels. It is extremely important that *all* milk should be held within the insulated zone so that undue loss of heat is obviated. With some types of holders, the covers are not insulated when, owing to surface cooling, all milk may not be maintained at the requisite temperature. This part of the apparatus is extremely important and if the whole of the covers are not properly insulated, particular attention must be paid to the temperature of the outgoing milk.

Surface cooling can be obviated by means of *air heaters* fixed in the holder compartments above the surface of the milk. These prevent loss of heat through the covers being left open accidentally, through lack of suitable agitation or owing to the absence of insulation of the covers. Experiments have shown that the air above the milk surface may be 5° to 10° F. cooler than the liquid itself. In the United States of America, where the provision of such heaters is compulsory, these usually consist of perforated steam distributor pipes through which controlled dry steam is discharged. Steam from the boiler is passed through a strainer which removes rust or other impurities, a steam trap removes water from the line while a second trap takes care of any condensate. This steam maintains the air temperature above the milk at least 5° F. higher than that required for pasteurisation, so that no surface cooling takes place. In order to heat the air in the separate compartments, steam is admitted to the distributor five minutes before milk is allowed to enter.

Agitation has been condemned by many authorities owing to the tendency possessed by incorrectly-designed agitators to cause foaming, although it is commercially essential in order to prevent cream rising and the formation of any membrane on the surface of the milk during the holding period. In any plant, the loss of heat may be greater at one point than it is at another, and agitation, if efficiently employed, overcomes this difficulty by ensuring that all milk is properly heated and maintained at the required temperature. Agitator paddles should not move at more than six complete swings per minute. The milk should never be agitated too rapidly nor should the agitators be put into motion before sufficient depth of milk is present in the holding compartments, otherwise the cream-line is likely to be affected. If some means of agitation are not provided, cream will readily rise to the surface of the milk and, as it is not advisable to fix a balancing tank between holder and cooler owing to damage to cream-line, and on account of the possibilities of re-contamination, the milk first drawn from the holder would be deficient in fat when bottled. There can be no objection to agitation if the paddles are designed to move at the speed mentioned above and it should be noted that this process is now compulsory in the United States of America. From a public health point of view, the provision of agitators complicates the cleansing of holding tanks, while further, if such agitation is not properly and carefully carried out, the risk of exposure of the milk to air will be increased. This favours the destruction of the vitamins and may impair the flavour.

Temperature control is of the utmost importance and both a recording and an indicating thermometer should be fitted at the combined outlets of the holders. These instruments must be placed in a good light where they may be easily inspected. When "Batch" holders are employed, a recording and an indicating thermometer should be provided for each tank.

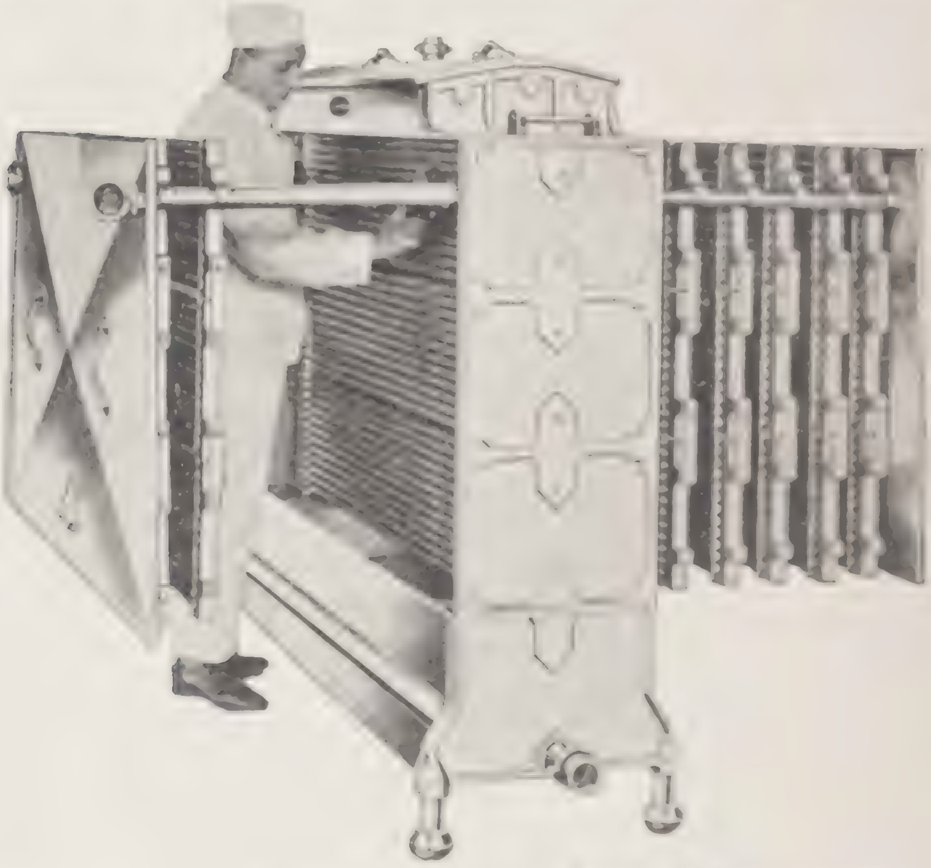
(vii) COOLERS. Cooling may exert a considerable effect upon the cream-line and tests have demonstrated that milk from surface coolers which are open to light and free to aerate, shows an improved cream line over milk which has been cooled in an enclosed apparatus. It would appear, therefore, that provided milk can be adequately protected during the process, a *surface cooler* will provide a more satisfactory cream-line.

The maintenance of cream-line, however, is a commercial and not a public health necessity and it is more important to ensure that milk is properly protected from re-contamination during cooling. Independent coolers are still to be found in many dairies, the old type of "*surface cooler*" predominating. With such apparatus, milk receives a primary cooling by means of water, followed by a secondary cooling with brine or other methods of refrigeration, principally chilled water. This type of cooler possesses many disadvantages, requiring a large amount of space, is very difficult to clean, and, if of the large capacity type, is extremely fragile, while there is invariably some loss of milk due to evaporation. The liquid occasionally freezes on the lower tubes, usually on account of bad management, while exposure to the atmosphere may give rise to re-contamination. Freezing the milk on the cooler will lower the cream-line and is partly responsible for cream-plug formation in the neck of the container.

The water-cooling section should be balanced so that the milk temperature is reduced to approximately 65° to 75° F., further cooling by means of brine or chilled water to 40° F. or less being provided. Surface coolers must always be protected from dust and dirt by means of a well-fitting metal shield preferably fitted with an inspection window, and should be designed so that only a thin film of milk passes over, in order to ensure a completely uniform interchange of heat and the extraction of this heat in an economic manner within correct temperature limits.

A cooler open to light and air, although protected from contamination, is extremely useful. As previously mentioned, the effect of light, and particularly of sunlight, is important, and it is desirable to aerate milk during the cooling process if this can be done without any danger of re-contamination. It must always be remembered that pasteurised milk has lost the greater portion of its initial bacterial content and is extremely liable to re-contamination if care is not exercised. To allow of aeration and exposure to light, a novel cooler of the "surface type" has been devised, the apparatus being enclosed in a glass case to which a supply of purified air has access.

A special *cabinet type of surface cooler* has been introduced into this country from America, and this consists of a series of surface coolers suspended on parallel rails totally enclosed in a metal cabinet. The number of sections depends upon the quantity of milk to be handled. Each section can be extracted in turn for cleansing purposes and the apparatus is more compact and requires less floor space in relation to the quantity of milk treated



By courtesy of [illegible]

FIG. 13.—Cabinet Cooler (open).

than the usual surface-type cooler. Cooling, in its final stages is effected by means of chilled water in place of brine.

Tubular coolers are sometimes employed, designed on lines similar to the tubular type of heater mentioned on page 59, but probably the most foolproof and useful cooler now employed in many dairies is the *heat exchanger or regenerative type of apparatus* already described on pp. 62 to 67, in which a primary cooling of the pasteurised milk is given by untreated milk passing [illegible] for processing. The temperature of the partially-cooled milk is further reduced by water, followed by brine or chilled water. It should be noted that if brine is allowed to remain in the apparatus overnight, corrosion of the stainless-steel plates will eventually occur, and for this reason this liquid should be removed when the day's run is over prior to cleansing operations taking place. With this type of cooler, chilled water may be employed in lieu of brine if desired.

It is important to remember that as the fat globules have collected in cooling, subsequent agitation should be avoided as far as possible. Whatever type of cooler is employed, there should be complete protection from any possibility of re-contamination and mixture with the cooling medium. Separate coolers must always be employed for raw and treated milk, while the outlet from the cooler to the bottling machine should be provided with the usual types of temperature indicating and recording apparatus. If bacterial growth in treated milk is to be entirely inhibited, it should always be cooled to a temperature below 40° F. and the liquid should be retained at this temperature or lower if the cream-line is to remain undamaged.

While direct-expansion refrigeration is rapidly taking the place of brine in surface coolers, it cannot be used in heat-exchanger coolers and has not been widely employed in the tubular type. Brine tends to set up corrosion, which is absent when direct-expansion methods are employed. Brine or chilled water is employed in plate or tubular coolers but, with the latter cooling agent, 50 per cent. more cooling surface is required than is necessary with the direct-expansion method. When chilled water is employed, the pipes which carry it to the cooler must be well insulated while the apparatus must be situated as near the cooling coils as possible in order to reduce refrigeration losses in transmission.

(viii). PIPE-LINES. Pipe-lines are extremely important units and should be kept as short as possible so that unnecessary pumping is avoided, in order to reduce any possibility of heat losses and to facilitate cleansing operations. There should be no "short circuits," "dead-ends" or "cold pockets" in pipe-lines, where milk may be retained outside the proper temperature limits and which are difficult to cleanse. This fault is generally due to unsatisfactory layout and can be avoided by careful planning. Pipe-lines should be easy to dismantle and cleanse and should be manufactured from stainless steel which will withstand constant scouring and sterilisation. The metal alloy of such pipes is uniform in composition so that there is no plated surface to wear off, while their inner surfaces are uniformly smooth and easily cleansed. Separate pipe-lines for raw and pasteurised milk are essential to prevent any contamination of the treated product and they must be capable of being broken up into short sections for cleansing purposes. All elbows, tee-pieces and fittings should be designed so that every part of their internal surfaces is clearly visible and couplings and unions should possess no corners, cavities or open seams where milk residues can accumulate.

Consideration of the design and installation of pasteurising plants would be incomplete without mentioning the *metal surfaces* employed in construction of apparatus.

Metals employed in the manufacture of the various component parts of plant require consideration owing to the possible effect of their surfaces upon milk coming into contact with them. The first essential is a surface which can be easily cleansed and scoured without damage, and which is hygienic, while the possibility of metallic contamination of the liquid must be avoided at all costs. The metal employed must be a good conductor of heat, must resist any form of corrosion or rough handling, be durable, easily and cheaply fabricated, and reasonable in price, while it should not exert any toxic or deleterious effect upon the flavour or keeping qualities of the product. It should be noted that no single metal will satisfy all these requirements.

Tinned copper has been employed for many years for dairy purposes and is satisfactory if the tin is reasonably free from lead, always provided that the tinned covering remains intact. Frequent cleansing operations tend to destroy this coating of tin and the copper, thus exposed, will influence the flavour of any milk with which it comes into contact within 24 to 48 hours. Pure tin is slightly soluble in milk but in itself has no effect upon flavour. It is impossible to employ equipment manufactured solely from tin on account of the inherent softness of this metal; for this reason it is usual to employ a copper base to add strength to the finished article. Tinned copper equipment is very serviceable for handling cold milk but it is not suitable for holders where the removal of burnt-on milk solids usually requires the employment of strong alkalies and friction. Cleansing materials readily eat away the coating of tin as does abrasive action, and before such equipment can be solely employed, improved methods of tinning copper require to be developed.

Glass-enamelled metals are largely employed for pasteurisers and storage tanks of all kinds. Milk does not affect such surfaces and no flavour changes will ensue. The glass coating is brittle, and care must be taken to ensure that it does not become chipped or cracked or the metal will become exposed to the milk with deleterious effect.

Aluminium is a suitable metal as it resists the action of milk of low acidity and does not influence flavour. It is largely employed in the construction of dairy appliances, but unless aluminium is pure, impurities present may render it subject to pitting. It is, however, extremely sensitive to electrolysis in contact with some metals and is attacked by strong alkalies or acid cleaners. This type of surface may be cleansed without injury by means of hot water to which a little water glass has been added or with properly inhibited alkaline or acid cleaners. During the war, Germany used an aluminium alloy for milk containers containing silicon and magnesium and this was found to give excellent results when oxidised and lacquered by a special process. This metal, which was light in weight, was extremely hard and strongly acid milk products or normal detergent solutions exerted no corrosive effect upon it. The surface may be anodised when the natural film of oxide is thickened to give a hard coating which possesses a high resistance to corrosion.

The ideal metal for the construction of dairy apparatus is *stainless steel*, which resists the detrimental effect of lactic acid and the various detergents used for cleansing purposes. This metal cannot be injured by scouring, is easily cleansed and will not stain or corrode, while its bright appearance is permanent; it has no electrolytic action and does not form any salts which are soluble in milk or injurious to health.

Chrome nickel steel has not been used in the manufacture of dairy apparatus for any length of time and, while up to the present it appears to be generally satisfactory, its employment over a more lengthy period may reveal limitations which are not at present apparent. It possesses most of the qualities of stainless steel but is very vulnerable to electrolytic action when in contact with certain metals. It must possess a highly polished surface and be free from iron oxide. *Monel* and *Inconel metals* are also extremely useful materials for dairy purposes.

Mechanically, these latter metals are more resistant to wear than are tinned copper or aluminium and therefore their working life is extended, while less repairs or renewals to the plant are required. The internal surfaces of such equipment are not susceptible to deterioration due to impact as is the case with glass-lined apparatus. These metals are quite as hygienic as glass, the only objection which can be raised to their use being the cost which is more than amply repaid by the economies obtained from their employment.

Refrigeration Plants. *Cold rooms* are essential for the storage of milk after it has been bottled and some form of refrigerator is required for this purpose and for milk cooling. The usual method of refrigeration is one which makes use of gas compression When gas is compressed, heat is generated and temperature is raised. On being allowed to regain its original volume, gas wil re absorb heat and cool to its original temperature, unless, in the process, some heat has been absorbed by the compressor. Thus when gas is first compressed and then cooled by coming int contact with a cold surface, it will absorb heat from its container The lower the temperature reached in compressing gas, the greate will be its ability to absorb heat when allowed to expand. This simply put, is the principle of refrigeration.

In the ordinary *ammonia plant* which is usually employe when large-scale refrigeration is required, the gas is compresse by means of a power-driven compressor, causing a rise in temperature and consequent generation of heat. The gas passe into condensing coils which are surrounded by cold water, the action of which lowers the temperature of the compressed gas which liquefies owing to the abstraction of its heat. The liquefie gas then flows through an expansion valve into expansion coil where pressure is low, and this area of low pressure allows the liquid to regain its gaseous state. As this process takes place heat is absorbed from the vicinity of the vaporising coils in the cold chamber. Brine or water is cooled in this manner befor being circulated through the milk-cooling system. The expande gas is then drawn back to the compressor, flowing into a crank case and the cylinders are filled by means of a piston. The stroke of the piston forces the gas under pressure through discharge valves at the upper extremities of the cylinders, a separator removing any oil from the compressed gas as it flows towards the condensing coils. *Condensers* are usually jacketed pipes arranged so that the heated gas enters at the upper end of the outer pipe and flows downwards, while cold water enters at the lower end of the inner tube and flows upwards. The lower the initial temperature of the water used and the greater is the refrigerating effect. The condenser may be easily dismantled for cleansing purposes.

Other reliable refrigerating plants make use of gases such as carbon dioxide, sulphur dioxide, methyl chloride or freon gas, and these will carry out their work in an efficient manner. The motive power is usually electricity. A " cold vessel " contains a chemical mixture composed of liquids which will vaporise at a low temperature and pressure. A pump removes the vapour which carries away heat extracted from the brine or from the cold chamber. In another part of the apparatus this vapour is re-condensed to a liquid, the heat previously absorbed being removed either by a flow of circulating water or a current of air. The process is continuous so long as power is provided and the pump kept in operation. Thermostatic control may be provided so that when the temperature of the cold room rises to a predetermined height, the motor is automatically switched on, the plant operating until the temperature is reduced to the requisite level, usually 40° F.

Certain important points require attention when the installation of refrigeration plant is considered. It is essential that the discharge pressure should be noted, an increased discharge pressure meaning extra power to operate the plant and *vice versa*. The pumping capacities of the various types of compressor should be checked and compared. This figure may be attained by multiplying the volume of the cylinders by the number of strokes per minute. The condenser is also important as the larger the surface provided, the quicker will be the heat transference between the cooling water and the condensing gas. The quality of construction is also of importance and spare valves should always be provided with any plant installed.

Milk storage rooms are often found to be wet and unsightly.

possessing slippery floors and dripping walls, and such room should be cooled by means of a forced air circulating system Direct-expansion ammonia coils should be arranged with baffle in a coil chamber which is located outside the room. A motor-driven fan distributes chilled air through ducts, and, once distributed, the air is returned over the coils to the coil chamber This method of distributing cold, dry air to every part of the room gives faster cooling of the milk and its containers, improving the keeping qualities of the liquid and its cream-line. The heat and moisture on the crates and bottles is removed simultaneously while any warm humid air infiltrating from the filling room i rapidly cooled and de-humified, the moisture being removed in the form of frost on the cooling coils. The room thus becomes clean dry and sweet-smelling, with a complete absence of moisture and a credit to the rest of the plant instead of, as is so often the case, a place to be avoided when visitors are conducted round the premises

Power Plant for Dairies. Steam is often employed in large dairies for the production of power and because large quantities are required for processing, although oil engines are also used for power purposes. Electricity has made rapid strides during the last decade as, when electric motors are used to generate the necessary motive power, several advantages accrue. The theoretical efficiency of the different types of power generators is as follows :—

	Per cent.
(*a*) Electricity	80–90
(*b*) Oil engines	40
(*c*) Steam turbines . . .	25
(*d*) Steam engines . . .	15

From the above figures, it will be seen that electricity possesses a clear lead over any other type of motive power as regards efficiency. In addition, the electric motor can be started or shut down quickly, is clean and requires no fuel while it occupies little space and is quiet in running. A further advantage is the fact that if a suitably-sized motor is provided to each piece of apparatus requiring motive power, shafts and belts are not required and this fact renders the installation of plant more economical. It is necessary to provide *speed regulators* with all electric motors, so that they start without taking on excessive load.

CHAPTER V

LOW-TEMPERATURE PLANTS

It is obvious that the type of pasteurising plant required will be governed by the quantity of milk requiring to be treated. The small operator will need apparatus widely different to that necessary for processing large quantities of milk and the types required by these two different interests now require consideration.

Manufacturers have made extraordinary progress during the last 30 years in the production of dairy machinery, having ably followed the lead given by scientists who have repeatedly demonstrated the need for better methods. At the present time, apparatus is obtainable which is extremely efficient while not excessive in price when its output and reliability is taken into consideration.

Before any plant is installed two considerations arise. Firstly, the apparatus must be highly efficient although the acquisition of such efficiency will most likely necessitate increased expenditure. On the other hand, it should be remembered that efficiency may not always be obtainable from a reasonably-priced plant and consequently losses to the operator may ensue. When compared with other trades, the plant operator is at a disadvantage. Milk is produced twice daily and on seven days per week and apparatus which will efficiently handle this constant flow of raw material in any quantity must necessarily be expensive. In selecting plant for dairy work, this need for constant operation should always be borne in mind together with certain other points requiring consideration. These are :—

(*a*) *Necessity for Duplicating Equipment.* This point is important. In the case of any breakdown, it is still necessary to deal with incoming milk which *must* be handled and cannot wait until repairs or renewals take place before it is processed.

(*b*) *Standardisation of Apparatus.* Spare parts must be kept in stock so that repairs may be undertaken with as little delay as possible. Without standardisation, a large and expensive stock of parts will be necessary.

(*c*) *Future Expansion of Business.* As previously stressed, care must be taken to ensure that all new apparatus installed is large enough to handle future business otherwise plant operation may become uneconomical.

(*d*) *Facility for Cleansing.* Plant must be capable of easy cleansing and should possess no awkward or inaccessible parts which the average dairy hand is likely to overlook.

(*e*) *Constructional Details.* The materials employed must be durable and likely to give long life in spite of constant usage and cleansing.

(*f*) *Need for Renewal.* Apparatus which has proved to be uneconomical or whose working life is only maintained by constant repairs and renewals should be ruthlessly scrapped. This procedure will prove to be more economical in the long run and will provide an assurance that satisfactory processing is capable of being maintained.

Low-temperature processing methods may be employed in two ways, according to circumstances, viz. :—

(*a*) "*Batch*" *pasteurisation* in which separate holders may be used, either singly or coupled together.

(*b*) "*Multiple compartment*" apparatus which is generally installed by large producers of pasteurised milk. The holding process is carried on without any loss of continuity in the supply of milk to the cooler and the bottling machines.

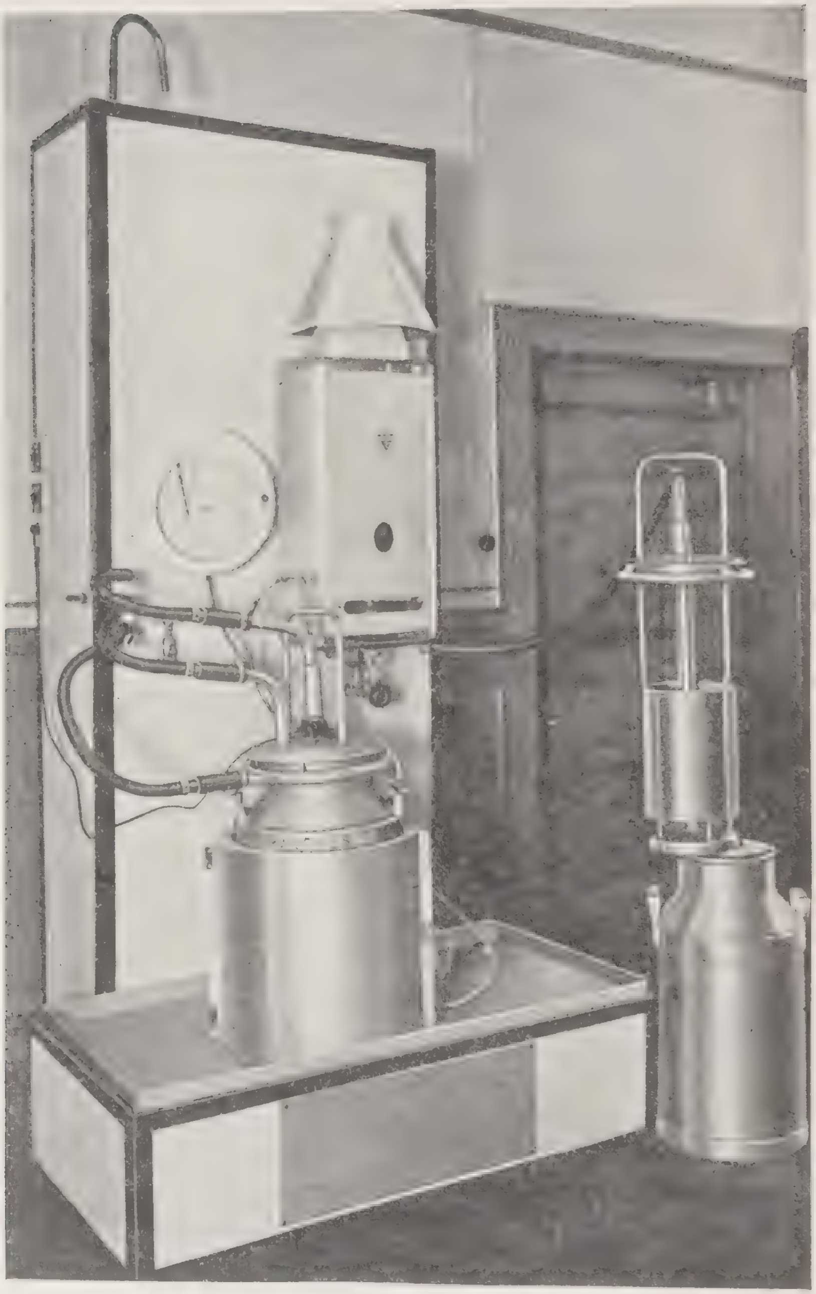
(*a*) **"Batch" Pasteurisation.** It has been mentioned previously that opponents of pasteurisation state that compulsory processing will force many small distributors out of business. This is not necessarily so, as efficient plants, suitable for small operators whose total output per day does not exceed 300 gallons, can be obtained which are both reasonable in cost and economical in operation.

"Batch" pasteurisers not only provide a method of treatment which complies with statutory requirements, but one which is quite suitable for the distributor with a relatively small trade. By suitable arrangement, it is possible for such apparatus to give continuous treatment and, generally speaking, this type of plant is both foolproof and economical. If properly designed and constructed, uniformly good results may be obtained, provided adequate care and attention is assured. The process of efficiently heating, holding and, if desired, cooling milk in a single vessel is one which should appeal to the small dealer, and a plant of this type is capable of handling from 50 to 300 gallons of milk per day according to the number of tanks provided. If desired, "Batch" pasteurisers may be arranged to give continuous output by installing the holders in series or in batteries. Single-vessel pasteurisers are to be obtained which have capacities varying from 10 to 100 gallons of milk.

but a number of smaller vessels is always preferable to fewer larger ones, if room permits.

It is often stated by the critics of the pasteurisation process that any compulsion to treat all milk in this manner would result in the extinction from business of a large number of producer-retailers. Such persons who, of necessity, would be required to pasteurise only a small quantity of milk daily have not, up to the present, been able to obtain any apparatus which would be economical to both purchase and maintain and which would carry out treatment in an efficient manner. In order to overcome this difficulty, the "*Hemming-Howell*" *Pasteurising Unit*, illustrated in Fig. 14, has been devised. A section of this apparatus is shown in Fig. 15. The prime heater of the unit is a gas- or coke-fired hot-water boiler, but the employment of an instantaneous gas heater (C) is the ideal method of heat production. If desired, the hot water from the boiler may circulate by gravity but a small electric pump (B) is to be preferred. This forces water through the boiler and raises it to a controlled temperature of 180° F., after which it passes through a flexible tube to the inlet (F) of the unit. Stainless steel or aluminium are the metals used in the construction of this unit, and the hot water passes through the centre pipe to a chamber at the base, afterwards rising through four pipes into an annular chamber which extends upwards for approximately three-quarters of the height of a churn and is connected, at its upper end, to an outlet pipe which passes back through the mouth of the container. The water passes up the pipe, through a flexible tube and so back to the boiler. For cooling purposes, a three-way valve (Q) is connected to a circular pipe attached to a lid and fitted outside the churn. This pipe is drilled with small holes facing towards the receptacle.

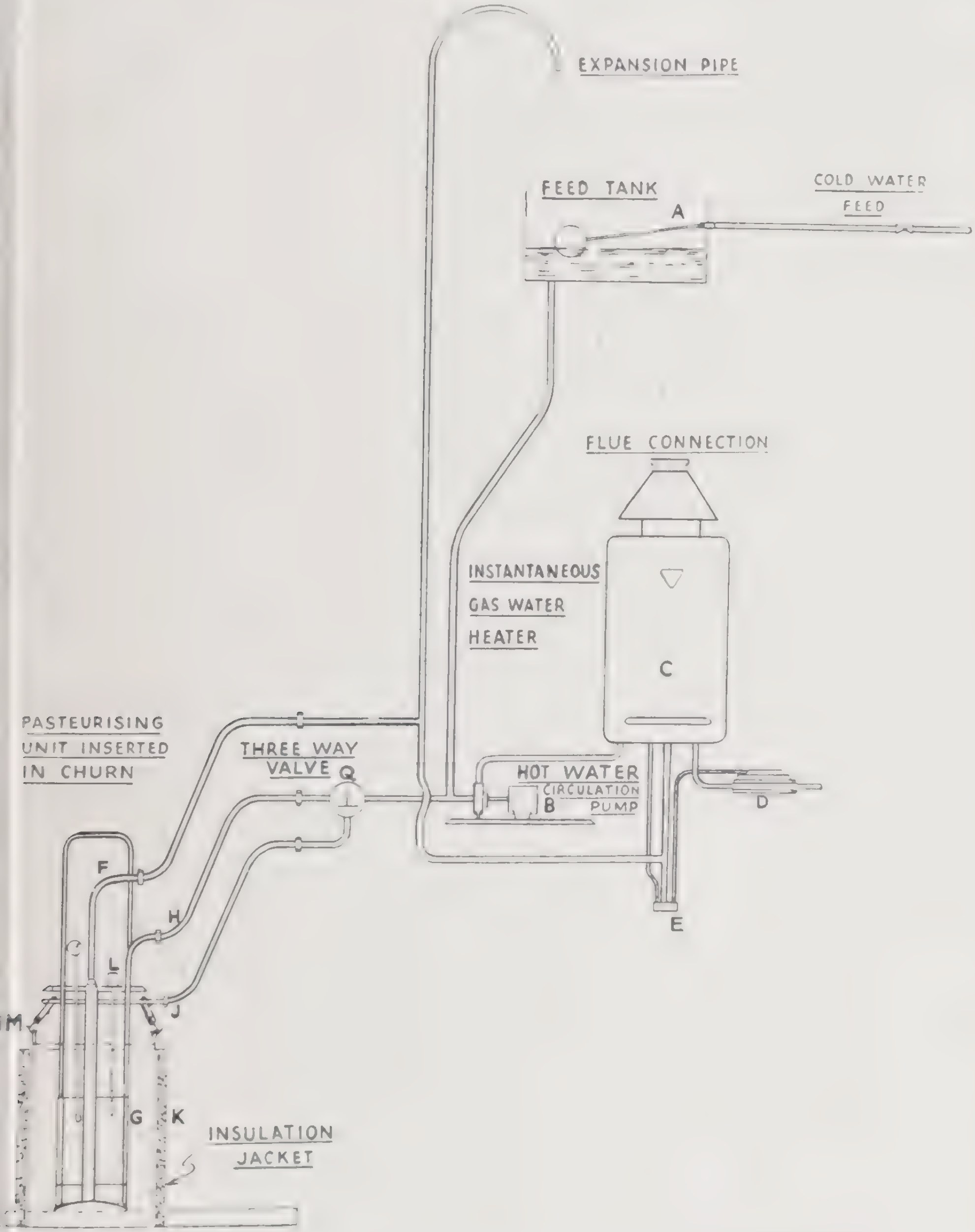
The unit heats the water to 180° F. within three minutes of operations commencing, and the gas is then shut down by the thermostat (E), the whole apparatus being thoroughly heated and sterile by the time the milk is ready for treatment. The milk is filtered and the churn is filled after which the unit is inserted in the liquid, the clips (M) are attached to the churn handles and the loose insulated jacket (K) is placed around the container. Milk direct from the cow at a temperature of 95° to 100° F. does not need to be cooled as it is treated almost immediately it is produced and the temperature is quickly raised



By courtesy of the City of Manchester Gas Department.

Fig. 14. "Hemming-Howell" pasteurising unit.

to between 145° and 150° F., after which the heat is turne
off either manually or by means of a thermostat. The electri
thermostat (L) shuts off the pump (B) which automatically cut



By courtesy of the City of Manchester Gas Department.

FIG. 15. "Hemming-Howell" pasteurising unit (section).

down the gas. The natural convection of the milk produces a difference in temperature between the top and the bottom of the churn of approximately 5° F. and this can be overcome by gently plunging the unit up and down through the sliding lid: no cream

separation takes place. The milk remains at the required ter
perature for 30 minutes after which the insulating jacket
removed and the valve (Q) opened so that cold water flows fro
the feed tank through the unit, being finally discharged as
spray down the outside of the churn and bringing the mi
temperature to within 5° F. of that of the water used in
minutes. The total operation is completed in less than one hou

If desired, one unit can be used for raising the temperature
the desired level and then removed from the churn to be employ
in a further churn. The milk will retain its temperature f
30 minutes and can then be cooled by means of a separate un
The units can, if desired, be used for cooling purposes only. T
cost per 10 gallons of milk treated averages between 2*d*. and 3
according to local fuel costs.

Pasteurisation is actually performed in the container and clean
ing is facilitated as the milk has not to pass through pipes, valv
or pumps. Should any accident occur, only a minimum quanti
of milk is affected, while there is no excessive agitation causi
froth or any continuously-heated portion likely to give rise
thermophilic infection. The milk is pasteurised direct from t
cow, bacterial growth being immediately arrested and, as
covered receptacle is used, no contamination from outsi
sources is possible, a safe, pure milk supply from a sing
herd being assured. The apparatus has been designed primar
for small producer-retailers and each unit is suitable for u
with either a 10- or 12-gallon churn. Both indicating a
recording thermometers can be fitted without difficulty as sho
in Fig. 14.

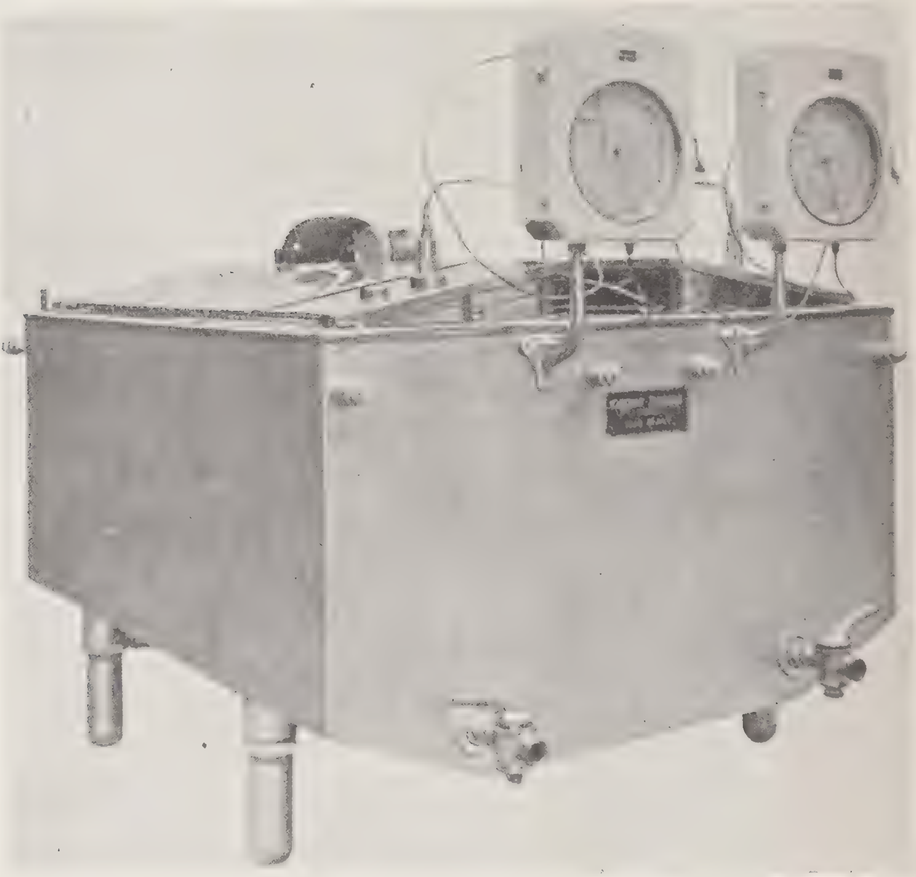
When dealing with milk in quantities above 100 gallons p
day, it is always advisable to have a series of pasteurising vesse
The combined heating surface of two separate holders is grea
than that of one large vessel of similar capacity and provid
for more rapid heating. As some time must elapse for filli
and discharging the vessels, the first tank can be put into oper
tion immediately filling is completed, when the second or sub
quent vessels are dealt with. Three tanks ensure that very lit
time elapses after the last vessel has been filled before the holdi
period of the first vessel is completed; while, if five tanks a
installed, continuous processing may be carried out. It is mu
easier to obtain a consistent temperature when dealing w

small batches of milk than is the case when a similar total quantity is treated in bulk.

So much is said about automatic plant at the present time that the usefulness of the "Batch" system is often overlooked but, if its modern design is studied, it will be seen that this type of apparatus is not secondary but equal, although in a different way, to the larger, automatic plant. For high outputs, it must be agreed that bigger plants provided with automatic operation and controls are necessary. For small or even medium outputs, however, the capital necessary for installation is not excessive and is more likely to be available. Dairy engineers have expended considerable time, energy and capital to improve the design of "Batch" pasteurisers so that no fault can be found with present-day apparatus of this type by the severest critics of the process. Further, it is important to note that these plants have been designed to meet the exacting requirements of the licensing authorities.

There are three types of "Batch" apparatus used for pasteurisation, although two of these are not employed at the present time to any great extent for milk treatment, having been superseded by the circular, jacketed vat provided with a paddle agitator. One of the original pasteurisers of this type is the *coil apparatus*, which is either rectangular in shape, being provided with a horizontal metal coil, or is a square tank which has a vertical coil. The sides and base are insulated, usually with cork, and hinged, insulated metal covers are also provided. In the horizontal type, the coil is constructed of hollow tubing, 1½ to 3 inches in diameter, which is suspended from a central shaft and passes through the ends of the apparatus. In the square tank, however, the coil is suspended from the cover. High-temperature heating water is passed through the coil as it continuously revolves during processing in order to secure uniform temperature throughout the contents of the tank and to provide the necessary agitation during heating.

The *spray-type apparatus* consists of one or more jacketed tanks, water at a temperature of 150° F. being employed as the heating medium. This is circulated by means of a pump through pipes located at the top of the jacket, being sprayed through apertures against the internal walls of the apparatus. This procedure assists in the even distribution of heat, the water which collects at the base of the apparatus being re-heated with steam for further circulation until the required temperature is reached. Agitation in each or every tank is provided by means of a slow-moving paddle during the heating operation. Apparatus of this type is usually equipped with automatic temperature control devices, the water-circulating pump being stopped when the desired temperature is attained. If the temperature falls, water circulation is automatically re-started.



By courtesy of Cherry-Burrell Ltd.

Fig. 16. Twin-spray pasteurising heater-holder.

The holder now most generally employed is a single circular tank in which the milk is retained for 30 minutes at a temperature between 145° and 147° F. This receptacle is designed to hold a specified gallonage of milk, and it should be free from recesses or pockets which might harbour bacteria or which would prevent the contents being retained at the requisite temperature. It should be easy to clean, be fitted with satisfactory temperature controls and possess an adequate heating surface to ensure rapid heat exchange. *Agitation* is essential to assist in the exchange of heat, but this should be insufficient to cause foaming or to prevent the subsequent rising of cream after treatment.

The apparatus is provided with a jacket to which low-pressure steam or hot water is admitted. This jacket should be designed so as to eliminate any heat loss during the holding period as when the correct temperature level has been reached and the holding period commenced, it is essential that there should be no fall in such temperature. It is normal practice to raise the heating agent to a slightly higher temperature than the milk is required to attain, but immediately this level has been reached, the steam or water supply is disconnected, the liquid being maintained within the necessary limits for the requisite period. In some plants of this type, provision is made for circulating the heating medium by mechanical or other methods. In this way, any possibility of " hot " or " cold " spots can be eliminated and the temperatures of the heating medium and of the milk may be efficiently controlled.

Milk treated in this manner should preferably be pre-heated prior to entering the tank as, if this is not carried out, some milk must of necessity remain in the holder for one hour or even longer before it is finally cooled and bottled. This lengthy waiting period may induce the " cooked " flavour so noticeable in sterilised milk. After treatment, cooling may take place by circulating cold water through the surrounding jacket. This procedure is naturally slow owing to the bulk of milk requiring treatment, and it is not conducive to low bacterial content, good flavour or satisfactory cream-line. Final cooling should always be carried out by means of a separate unit, but if desired the water jacket may be employed to supply a primary cooling before the liquid passes to the final apparatus.

It is essential to ensure that no milk is held *outside* the heated jacket of the holder, and it is also desirable that pumps and pipelines used for untreated milk should not be employed for handling the liquid after treatment. Such auxiliary apparatus requires to be efficiently washed and sterilised between filling and discharging takes place, unless duplicated. The holder may be filled or discharged by hand or automatically as desired, although, if at all possible, hand filling should be avoided at all costs.

The figures given in Table 2 below are supplied by Messrs. Aveling-Barford Ltd., to illustrate the numbers and sizes of " Batch " holders required for treating quantities of milk ranging from 100 to 300 gallons per day.

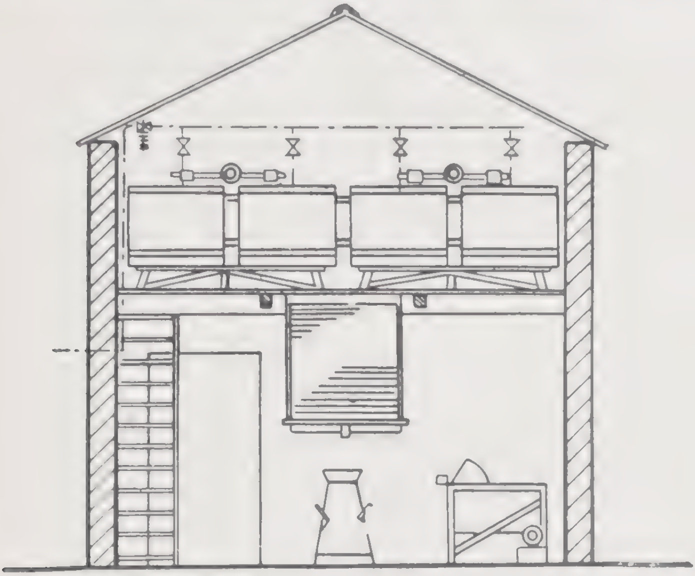
TABLE 2

Gallons to be Treated Daily.	Pasteurised in		
	One Batch. Gallons.	Two Batches. Gallons.	Three Batches. Gallons.
100	2–50	50	40
150	3–50	80	50
200	5–50	3–50	2–50
250	5–50	3–50	2–50
300	6–50	3–50	2–50

This information relates to the installation of the " *Econom* " pasteuriser but is applicable to all types of " Batch " apparatus.

The method of installation may be varied as desired. The holder can be raised on a stand to a height of about 2 feet 6 inches above floor level, its contents being discharged into a bucket after processing has been completed. This method is not to be recommended, and should be adopted only in the smallest dairies, considerable handling of the milk being necessary. When this method is employed, milk is strained on entering the holder by means of a removable strainer fixed above it. After processing has finished, the liquid may be discharged either into a bucket or can, or pumped to a receiving tank fitted over the cooler. If it is necessary to resort to pumping, it is desirable that the holder should be raised above floor level, this method of installation providing easier access. When provision is made for pumping milk to the cooler, a pipe-line filter is sometimes inserted between the pump and the cooler, but this practice has nothing to recommend it.

An alternative method of installation is to fit the holder on a platform well above the general floor level as shown in Figs. 17 and 18. If the height of the building will allow, this method is to be preferred as milk after treatment flows by gravity to the cooler and pumping is not required. Milk is emptied into a receiving tank at floor level, being pumped to the holder through a pipe-line filter. The platform on which the apparatus is installed must be provided with suitable means of access and should be of sufficient size to allow adequate room for cleansing operations. Of the two methods outlined, the one illustrated is to be preferred as the milk is only required to pass through a minimum amount of pipe-line after processing has taken place.



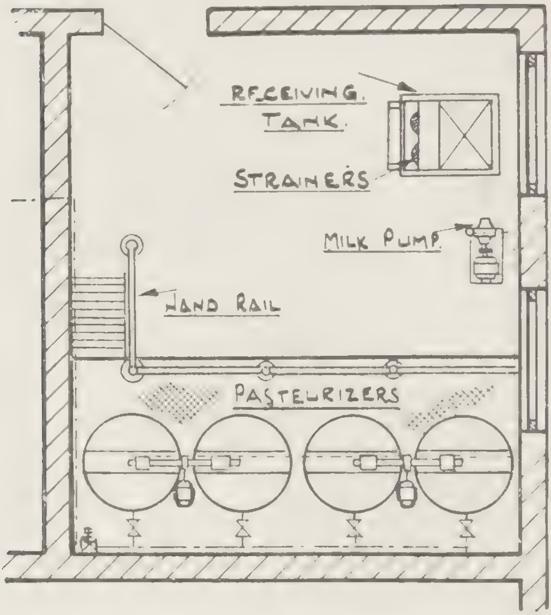
By courtesy of Aveling-Barford Ltd.

FIG. 17. Section. "Econom" pasteurising installation. Holders mounted at high level.

There are many efficient types of "Batch" pasteuriser to be obtained which, while complying with official requirements, are reasonable in cost and economical in operation. Such apparatus may be purchased in separate units while extensions are easily and economically carried out as required, always provided sufficient room has been allowed for business expansion.

The "*Econom*" pasteuriser, illustrated in Fig. 17, is designed to heat and hold milk in one vessel while, if desired, the product may be given a preliminary cooling in the holder after treatment is completed. The internal container is constructed of stainless steel and is surrounded with a jacket, the heating agent being low-pressure, low-temperature steam. The container may be insulated if desired and this is advisable as it prevents heat losses and gives economy in steam. When the required temperature has been reached, the steam valve is closed and condensation takes place. During the period the milk is held, a non-conducting vacuum is formed within the jacket. This is claimed to be more efficient than any form of insulation in preventing loss of heat during the holding process. As the container discharges, cold water is allowed to circulate through the jacket to effect a primary cooling of the milk. If water is used as the final cooling medium, the makers of the plant recommend a large-surface cooler.

If desired, the holder may be heated with hot water in lieu of low-pressure steam. When this method is employed, the jacket surrounding the container is filled with water to the required level, steam being admitted to act as the heating agent. The heated water is then withdrawn from the jacket and replaced with steam in order to form the vacuum so essential for insulation during the holding process. A hot-water circulating boiler may be used if steam is not available. Hand-operated or mechanically driven agitation can be provided, the hand-driven type being standard. The hand agitator requires to be operated by the person in charge at regular intervals. If the power-driven type is fitted, the plunger moves slowly in a longitudinal direction. With the steam-turbine-driven agitator, waste steam from the turbine can be employed to pre-heat the milk. Agitators may be coupled when two or more holders are employed.



By courtesy of Aveling-Barford Ltd.

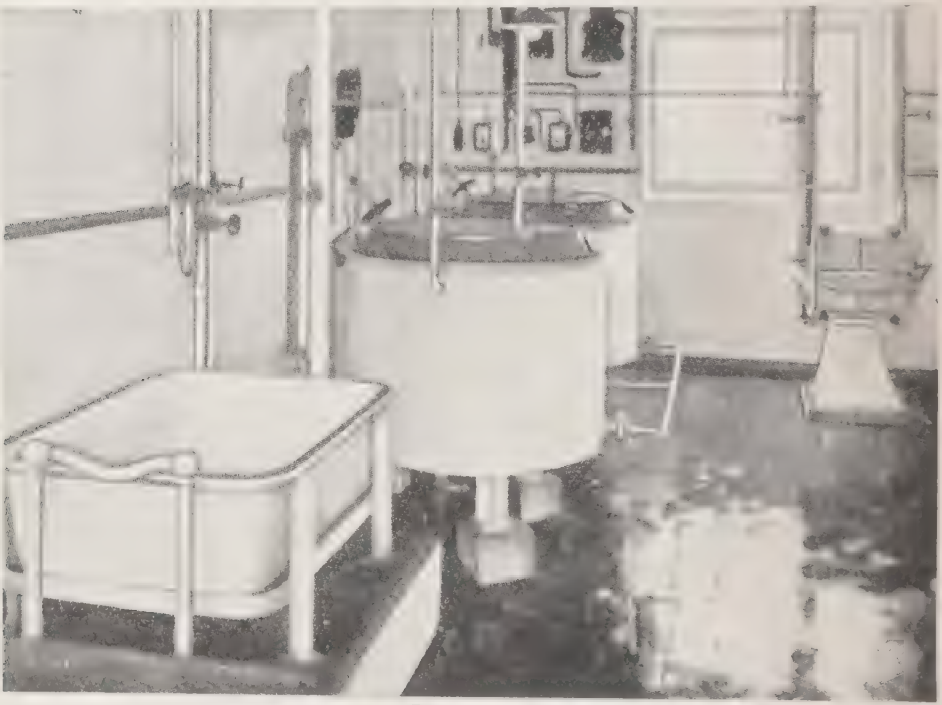
FIG. 18. Plan of "Econom" Pasteurising Installation.

Each tank is fitted with a standard indicating thermometer, but, in addition, a *self-recording thermograph* should be considered essential. This latter instrument must be fixed in close proximity to the holder in order that the final milk temperature may be recorded. *Thermostatic control* can be provided to operate in conjunction with the thermograph if electric power is available. This automatically disconnects the heating agent when the required temperature has been attained, the entire process being foolproof.

Either a single pipe-line filter or a continuous filter, which consists of two filters coupled so that one may be operated during the time taken to change the filtering medium in the other, can be employed with this plant. This apparatus consists of a circular steel box, heavily tinned or a stainless steel container. An air-tight lid is fitted on the internal surface of which is a spring which presses upon the perforated steel strainer plate. This plate covers a wire gauze disc, under which is placed the filtering medium, the whole resting upon a second perforated steel plate which in turn rests upon the grooves provided inside the apparatus. The whole filter is quickly dismantled for cleansing and sterilisation. Milk enters near the base, flows upwards, and is delivered through an upper outlet. A small quantity of liquid remains after filtration, and this should never be mixed with that which has passed through. For this reason, the through cleansing of the filter after processing has been completed is essential. This apparatus has the advantage of being entirely sealed during operation, thereby avoiding any atmospheric contamination while no wastage of milk occurs through splashing. The liquid presses evenly upon all parts of the filtering medium and filtration takes place against gravity so that all sediment drops to the base of the container, thus eliminating any possibility of dirt being washed through the filter.

The *A.P.V. "Batch" Pasteuriser* is an extremely efficient apparatus which is suitable for the small distributor. It is provided with a closed-circuit cooler in the form of a pedestal heat-exchanger possessing both water- and brine-cooled sections, and it may be adapted for use with the vacuum-and-compressed-air system of operation, thus avoiding any need for pumping. Fig. 19 illustrates a plant of this description, comprising two nickel "Batch" pasteurisers, tipping tank and pedestal heat-exchanger cooler.

The *C.P. Junior "Batch" Pasteuriser* is manufactured to a standard capacity of 100 gallons. The holder is constructed of stainless steel which is surrounded by a water jacket, the heating agent being a mixture of steam and water. During the holding period, the milk is agitated by means of a motor-driven paddle to ensure maintenance of a uniform temperature. The outer shell is also constructed of stainless steel, and covers the insulation which takes the form of 1-inch cork slabs. An indicating thermometer is provided as a standard fitting but, if desired, a recording instrument can be fixed. The principle of operation is simple. The holder is filled by hand, after which the steam and water valves are opened and heating commences. The agitator is started, and when the milk reaches the desired temperature the heat is disconnected for the entire holding period, the temperature being maintained by means of the cork insulation. After treatment, the milk is pumped whilst hot through an "in-the-line" filter to the cooler. An open tubular cooler is provided which may

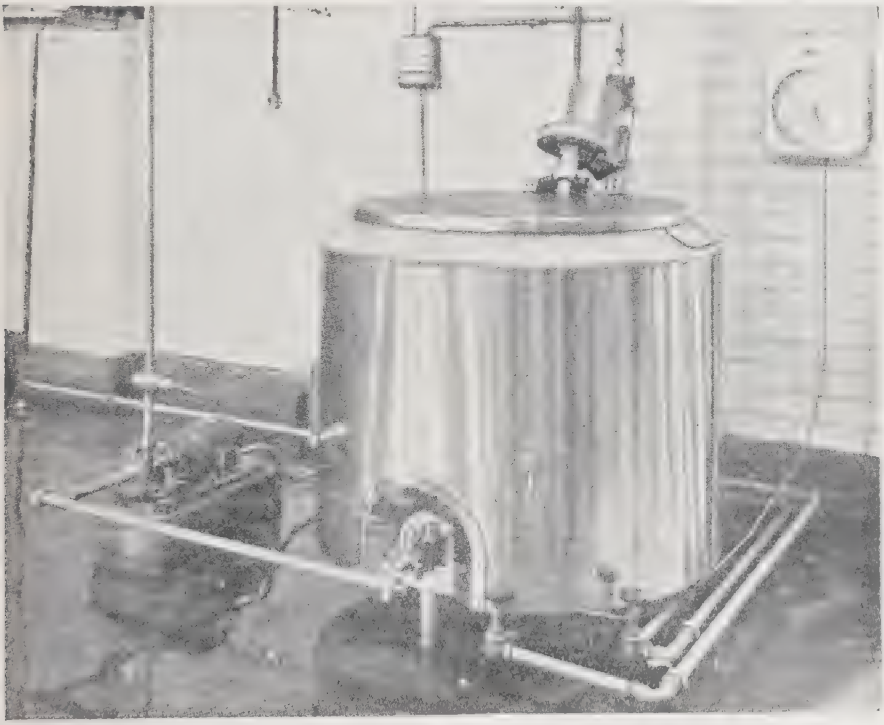


By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 19. A.P.V. batch pasteurisers.

be used for either single or double waterway, gravity feed being provided to the bottle filler. The final cooling agent may be brine or other refrigerating agent and the plant is quickly and easily cleansed. This plant is illustrated in Fig. 20.

(*b*) **"Multiple Compartment" Apparatus.** While the small distributor is able to obtain plant at a reasonable cost which will treat the milk in a satisfactory manner, the large operator, by reason of the huge quantities to be handled, must necessarily provide more expensive equipment. With the exception of the high-temperature short-time process, the low-temperature method of processing is the only operation which can be recognised by public health authorities as entirely efficient. Further, if milk is to be sold under the designation "Pasteurised," this system is the only one which fulfils in a reliable manner the statutory conditions, short-time pasteurisation of course excepted. How the liquid is retained is immaterial, always provided that time



By courtesy of the Creamery Package Co. Ltd.

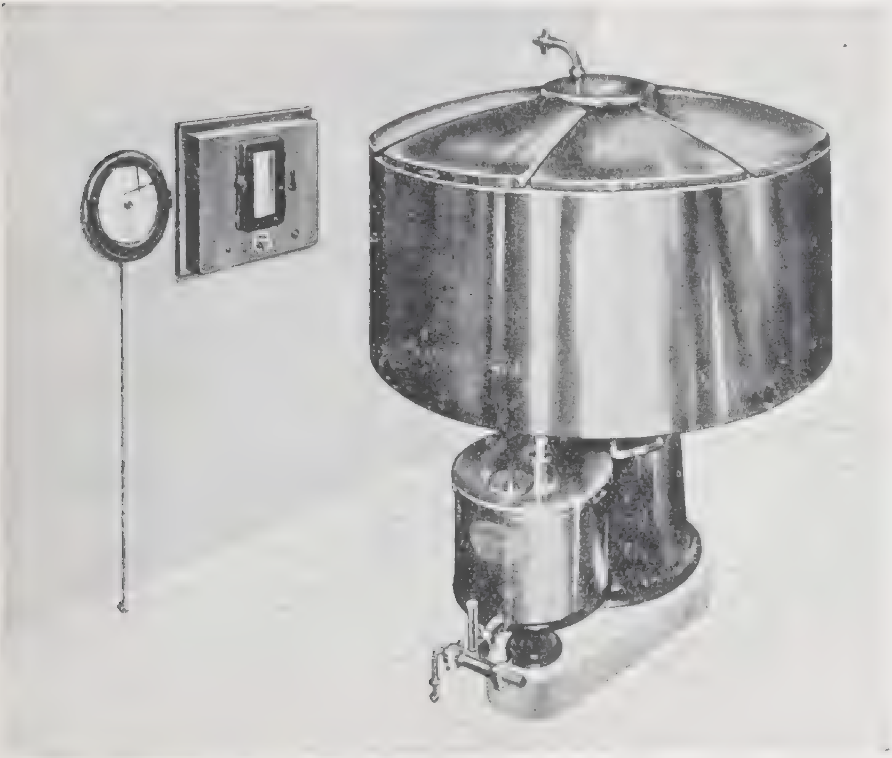
FIG. 20. C.P. Type "B" pasteurising plant.

and temperature are satisfactory. Owing to the fact that the high-temperature short-time process only received official approval a few years ago, many large processing dairies possess plants of the low-temperature type which were installed originally to eliminate any risk of faulty treatment. This method of processing is really an extension of the "Batch" system, the apparatus being provided with several compartments or tanks which may or may not be housed within a single framework. Usually efficient controls are provided and all operations fully mechanised so that only a breakdown in the controlling system or bad management can result in faulty processing.

Continuous action is obtained by the provision of a number of large tanks or holders coupled so as to ensure that the outflow of treated milk is continuous. The simplest method of obtaining continuity would be to provide three tanks so arranged that while the first tank is being filled, milk is held in the second and the third is being discharged. The three tanks should possess the same capacities and the inflow and outflow of milk should be so arranged that it will require exactly 30 minutes to fill or discharge each container. This would ensure a holding period of exactly 30 minutes. There are, however, two objections to this method. It may happen that some of the milk may be held for a longer period than 30 minutes, while approximately one hour must elapse before the pasteurisation of any one batch of milk is completed. In order to overcome these objections, it is necessary to provide a sufficient number of tanks in plants dealing with large outputs so that the time required for filling or discharging is considerably reduced. This is achieved by charging a set of containers in turn with pre-heated milk, leaving each container undisturbed for the necessary holding period and allowing each to discharge in strict rotation to the cooler.

There are three main types of apparatus for handling large quantities of milk. One type consists of a set of containers, each filling through its own valve from a common supply pipe and discharging through the same or through separate valves into a common main. The principal fault of this design is that it may allow the untreated milk to come into contact with milk already pasteurised, as the containers are frequently discharged by means of the filling valve. This system allows a faulty valve to contaminate the treated milk. In modern apparatus of this type, inlet and outlet valves are kept apart and, by means of special leakage grooves which are provided, any milk which escapes past the valve falls clear of the system.

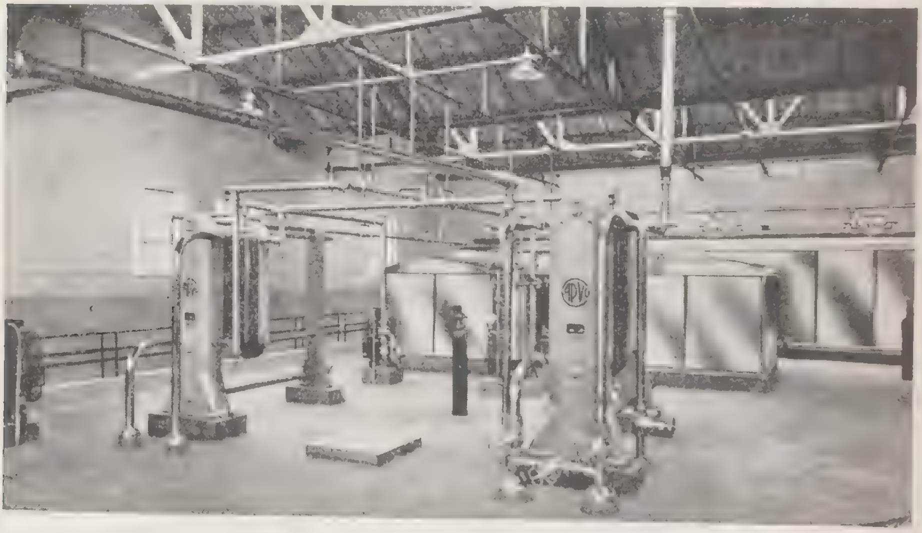
Another design provides a set of six containers systematically rotating in a clockwise direction in relation to common filling and discharging devices from which each compartment is disconnected. In some instances, the compartments may be fixed while the filling and discharging devices revolve. Pre-heating of the milk is carried out prior to the filling process and this type of apparatus has proved very popular in this country in the form of the "*Tarbet*" holder shown in Fig. 21. This apparatus embodies the idea of complete isolation of the milk while being held, from either the raw or the treated products. Since its introduction in 1922, the plant has remained substantially unaltered in design. In practice, the flow of milk must never be excessive or the danger of milk flowing from one compartment to another will arise. Care



By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 21. A.P.V. "Tarbet" holder.

must also be taken to ensure that the receiving or balancing tank into which the liquid is discharged after holding is not allowed to remain uncovered. Several advantages are claimed for this apparatus. The whole of the milk is maintained within the temperature limits required for the specified period. Each compartment is filled in 7½ minutes and is discharged in a similar period, the complete cycle of the containers occupying 45 minutes. The entire volume of milk is held inside the apparatus and none can remain in pipe-lines, outside the holder, while there are no supply or discharge pipes common to the various tanks. It is therefore impossible for leaking valves to allow partially treated milk to pass out to the cooler or for treated or untreated milks to mix. Operations follow in the correct order without any manual control and milk cannot enter any compartment until the outlet has been closed. The apparatus possesses a minimum of valves and pipes, no foam is created nor is the milk excessively agitated, while the necessary hydraulic power for moving the compartments is derived from the ordinary water supply.

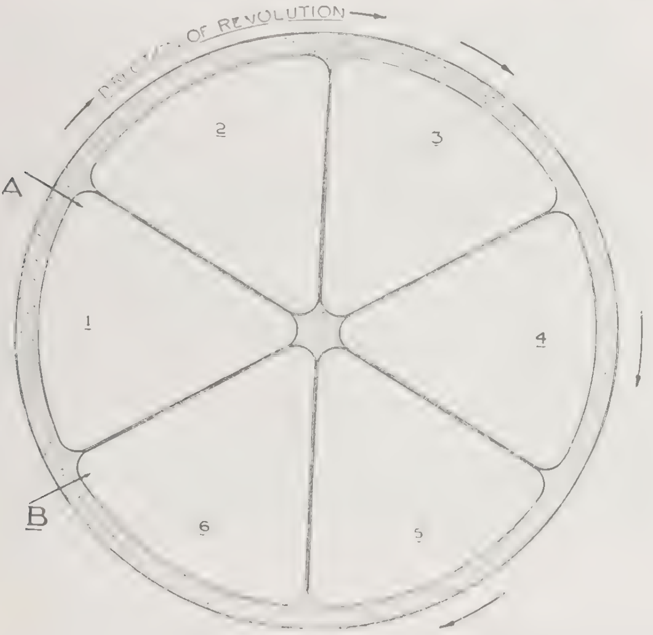


By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 22. Modern A.P.V. pasteurising plant.

In the third type of apparatus known as the "Individual Tank System," each compartment is a separate tank which may hold any quantity of milk up to 1,000 gallons. These tanks are independent of each other but possess common filling and discharging devices, are provided with covers and are insulated against heat losses. The vacuum-and-compressed-air system of operation can be usefully employed with this type of apparatus. Multiple compartment plants should be constructed in as simple a manner as possible while milk should flow from the receiving tank by gravity or other means throughout all processes.

With any of the above-mentioned plant, pasteurisation cannot fail to be satisfactory, always provided milk is delivered to the holders at the correct temperature, that heat losses are properly guarded against and that there is no misuse due to the failure of the human element.



By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 23. A.P.V. " Tarbet " holder (plan).

The *A.P.V. Pasteuriser* is one of the most popular plants installed both in this country and on the Continent, and it was designed with five main objects in view, as follows :

(1) To provide an apparatus in which milk, during all heating and cooling operations, is not in contact with air, thus preventing any risk of air-borne contamination.

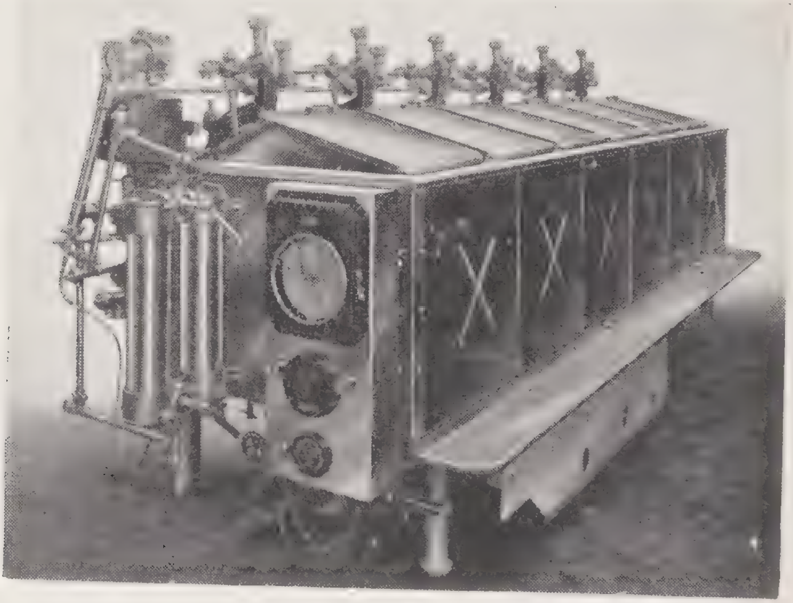
(2) To ensure that every surface brought into contact with milk can be readily cleansed, and that the whole plant allows of easy sterilisation before and after running.

(3) To provide a method of heating in which it is not essential to bring milk into contact with any steam-heated surface.

(4) To enable the entire process to be carried out with economy and without the creation of foam.

(5) To provide a plant in which efficiency of heating and cooling can be reliably calculated and in which such efficiency remains unaffected by water, brine impurities or scale.

The principal features of this apparatus, in addition to the holding tanks, are the *continuous filter* (see p. 69), the *plate heat-exchanger* (p. 62) and the *vacuum-and-compressed-air system* of operation (p. 72).



By courtesy of the Creamery Package Co. Ltd.

FIG. 24. C.P. "Auto-precision" pasteuriser.

The *A.P.V. "Tarbet" Holder*, already mentioned on p. 101, is another popular apparatus suitable for medium-sized dairies and its operation is illustrated in Fig. 23. At point A, milk from the pre-heater is flowing continuously into the compartment below. After leaving this point, the compartment moves slowly round in a clockwise direction to point B, where it remains stationary until the contents of that particular compartment are discharged into the balancing tank below. From this position, the milk is either pumped or flows by gravity to the cooler. The time taken to move from point A to point B is exactly 30 minutes as specified by legal enactments. During processing one tank is filling, four are holding milk and one is discharging its contents.

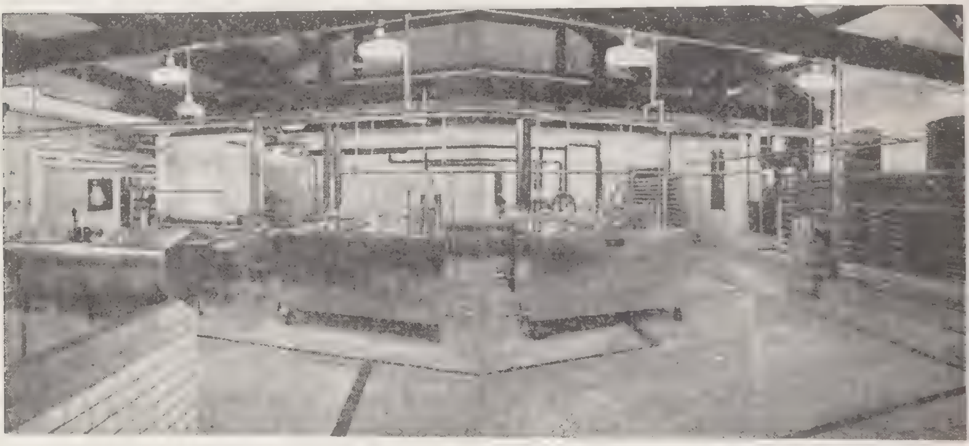
The *C.P. "Auto-precision" Pasteuriser*, shown in Fig. 24, has been designed to give exact precision in operation, in order to comply with statutory requirements. It is entirely self-contained with the exception of a separate cooler, and consists of heater, holder, which is divided into four compartments, and cooler. Milk is pumped from the receiving tank through a three-stage heater and, after filtration, passes to one of the holder compartments. When the holding period has been completed, the milk is drawn by means of an exhaust pump to a compartment over the cooler. Temperature control is exceptionally complete, full temperature recording being provided, while the temperatures of the milk entering and leaving each compartment are also recorded. The plant is entirely automatic.

The heating of the pre-heater and holding compartments is combined, the same heating medium serving both sections. The heater tubes are of stainless steel and pass through the body of the holder. These can be rapidly dismantled for cleansing and sterilisation. The heating medium is steam-heated water, the heating of this water taking place away from the holding vessels. The volume of heating water circulated to the quantity of milk to be heated is in proportion of 20 to 1, heat interchange being remarkably complete.

The two main features of the plant are the temperature of the water used for heating and the automatic method of temperature control. The heating medium circulates continuously and is at no time higher than the pasteurising temperature. The temperature-regulating system is operated by means of compressed air. Any increase or decrease in the temperature of the heating medium is instantly balanced by the closing or opening of the steam regulator valve, and there is no possible chance of either insufficient or excessive heating. The holder compartments are constructed of stainless steel with all corners rounded, a sump and draw-off plug being provided in each compartment. During the holding period these are sealed from the atmosphere, and are provided with agitators.

Milk after treatment is drawn from the bottom of each compartment, the inlet pipes being carried to a similar position in order to ensure complete absence of foaming during filling operations.

Inlet and outlet valves are of the positive type, and, when closed, "break" the flow pipe-line, thus preventing any untreated milk passing to the holders. By-passes are provided for any leakages from valves. The cooler is of the tubular surface variety, the size being arranged to suit the capacity of the holder. Cooling is carried out primarily by means of water, followed by treatment with chilled water, brine or by direct expansion refrigeration. A large surface area is provided to ensure rapid cooling, while a flow distributor is fixed to secure a thin, even film of milk over the entire cooling surface. This plant is entirely automatic, is simple to operate, one gear lever starting the whole apparatus into motion. For its capacity, it occupies a remarkably small space.



By courtesy of Cherry-Burrell Ltd.

FIG. 25. Complete Cherry-Burrell pasteurising plant, showing heater holders and coolers.

The system employed in the "*Cherry-Burrell*" *Pasteuriser* does not differ materially from the standard types of plant but, by the provision of efficient temperature controls and automatic stopping and starting devices, labour can be almost entirely eliminated. The "*Uniflex*" *Internal Tube-section Heater*, which is one of the methods of pre-heating employed, consists of a bank of double tubes. Hot water is the medium provided, and this circulates through the annular space between the tubes while the milk, after filtration, passes through inner tubes. Two types of heater may be obtained. For plants with a capacity up to 300 gallons of milk per hour, the heater has single or double heat control. If over 300 gallons per hour require to be treated, double response heat control is fitted. The temperature of the heating water is lower than in many types of plant, this being made possible by the design of the heater and by the circulation of a quantity of water in high ratio to the quantity of milk treated. Perfect temperature control is obtained, the makers claiming that temperatures can be regulated to within one-tenth of a degree Fahrenheit during processing.

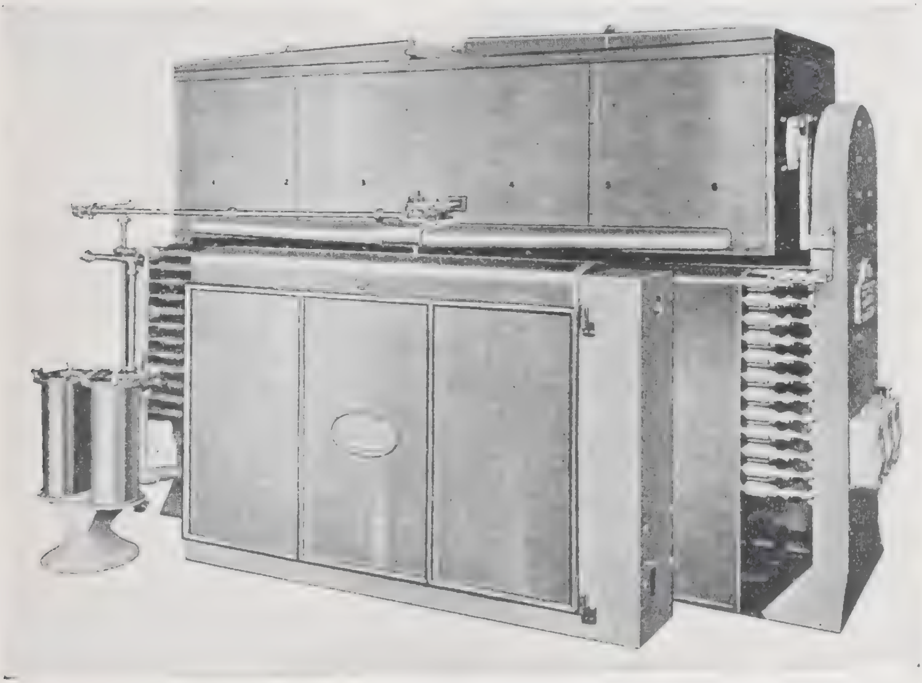
The "*Superplate*" *Heater* can also be employed for pre-heating purposes. This is a plate heat-exchanger using re-generation on the lines already discussed on p. 62. The plates are not grooved, but are provided with "knobs" which interlock, forming channels through which the milk passes. Improved gaskets are fitted, and these are claimed to be extremely strong, being bonded into the metal so that the gasket itself will tear before the bonding breaks. These have been designed to prevent any troubles arising on account of loose gaskets which have always been one of the difficulties with this type of apparatus.

The *holder* allows no re-contamination of milk on account of faulty valves. The liquid is fed into the compartments from below to avoid formation of foam, and, after treatment, is drawn off by entirely separate pipes. It is impossible for any untreated milk to come into contact with that which has been processed. The holder is divided into compartments which are filled by means of a divided bowl, and over this a revolving cover directs the milk into each compartment in turn. The holder compartments are divided into two groups with the controlling mechanism in the centre. These tanks are constructed of chrome-nickel steel and are suitably insulated by means of an air jacket which overcomes any difficulty likely to arise on account of temperature drop during the holding period. The air between the inner and outer tanks is heated by means of a steam coil to a temperature of several degrees higher than is required for the process. This minimises heat-loss which is likely to occur when water is used. The temperature of the milk is not affected during the holding period, although the air temperature in the jacket may be higher than 145° F. A paddle agitator is fitted to each compartment which moves at the rate of six strokes per minute, thus ensuring complete uniformity of temperature. Tightly-fitting, heavily-insulated covers are provided to prevent air contamination, heat losses and losses through evaporation. Milk is discharged from the holders by siphonic action, siphonage being induced by means of a rotary pump. When discharge has begun, milk continues to leave the compartments by gravitation, the pump acting as a flow regulator. When the gravity system of discharge is employed, it is sometimes difficult to maintain an even flow of milk over the cooler on account of the head of milk at the commencement of discharge which is liable to overtax the apparatus. This results in a considerable amount of milk being improperly cooled. Similarly, when a compartment is almost empty the head of milk is decreased, only a small quantity passing over the cooler with the result that the liquid which is passed is overcooled and often becomes frozen on to the lower section of the apparatus. By reason of the regulated siphon provided, an unvarying flow of milk to the cooler is maintained, ensuring maximum cooling at all times. All working parts and controls are encased in a central cabinet. The controls are entirely automatic and efficient temperature controllers and recorders are connected at requisite points.

A *cabinet cooler* is available in all sizes to treat from 200 gallons of milk per hour upwards. Owing to its design, it is claimed that there is a considerable saving in refrigeration costs and a material improvement in the quality of milk treated. The cooler is capable of reducing the temperature of milk from 145° F. to 40° F. in three seconds and, owing to the height of the cooling surface (4 feet), a minimum of agitation occurs during the process. The cooler possesses a large surface area and the tubes are of small diameter. Owing to the extensive surface area, brine or chilled water at a much higher temperature may be employed with a consequent saving in refrigeration costs.

The *"Gem" Unified Treatment* plant, shown in Fig. 26, is designed to overcome the need for a large amount of space, complicated pipe-lines and separate units so often found necessary. A reduction in the capital cost of plant and buildings is effected and a saving in labour costs and maintenance expenses is also ensured. This apparatus is a complete milk treatment plant, compact yet simple and complying in every respect with the requirements of licensing authorities. No pumps or vacuum pipes are required, the flow of milk being entirely dependent upon gravity. The liquid is at no time exposed to air during treatment while metal surfaces in contact with the fluid are constructed of stainless steel, thus rendering cleansing operations a comparatively simple matter.

A complete 400 gallons per hour unit occupies a floor space of approximately 44 square feet, and by reason of its small size the apparatus will be found useful to those distributors whose space is limited. Units are constructed in various sizes, treating any quantity of milk from 75 to 2,000 gallons per hour. The liquid is first pre-heated by regeneration, the heated milk from the holder exchanging its heat with the incoming cold liquid. This partially heated milk receives a further heating to a temperature of 145° F. by a tubular pre-heater, milk passing through the inner tube where it is heated with hot water contained in the annular space surrounding it. The milk tubes are constructed of stainless steel and are easily accessible for cleansing purposes. Automatic temperature control is provided which facilitates accurate working. After final heating, the milk passes to the holding portion of the apparatus, into a set of insulated vessels where it is retained for the required period. The holder is constructed so that the entire



By courtesy of the Graham Enock Mfg. Co. Ltd.

Fig. 26. "GEM" milk treatment apparatus.

volume of milk is drained from the vessels into the cooling system, there being no pipes between holder, cooler and cold milk balance. Separate outlet valves deliver milk directly over the cooler, any leakages arising from these valves being led away to waste. The holding vessels are mounted over the cooling section upon the top of the apparatus and swing down for cleansing purposes. There are no dead-ends or by-passes. On leaving the holder compartments, the milk is cooled to a temperature of 40° F. in three stages. As already mentioned, primary cooling takes place by heat-exchange with the incoming cold milk; a secondary cooling is given by mains water to within two or three degrees of the temperature of the cooling agent, while final cooling is effected by means of chilled water. "Freezing-on" with consequent injury to cream-line is avoided. Arrangements are incorporated whereby the heater is able to be used to raise the temperature of the milk to 145° F. without regeneration during the first half-hour after the plant has commenced to operate when no hot milk is available for pre-heating purposes. An additional water supply is passed through the mains water-cooling section during the last half-hour the plant is in operation, where there is no incoming cold milk to pre-cool the hot liquid.

All controls are centralised and the instrument panel shows:

(*a*) Temperature of hot milk.

(*b*) Temperature of cold milk.

(*c*) Temperature of chilled water.

Recording instruments can be fitted if desired, this being most essential. Special sight windows are provided by means of which processing can be noted. This plant should solve the problem of those distributors who have little space at their disposal and who, for economic reasons, cannot alter or rearrange their premises. It should appeal to such persons as a solution of their many difficulties.

CHAPTER VI

TEMPERATURE CONTROL

It should always be borne in mind that pasteurisation, if it is to be above suspicion, is an extremely scientific process and for this reason, accurate temperature control is an absolute necessity. While this is extremely important when dealing with the low-temperature method of processing, on account of the extremely small margin of safety provided by short-time pasteurisation, such control becomes still more important. If temperatures cannot be accurately relied upon by the provision of efficient controls, the suitability of any plant for the work for which it is intended will be nullified, however well designed it may be. The owner of the plant requires to be assured that the milk is not overheated during treatment with a view to the preservation of the cream-line, while it is also essential, from the public health standpoint, that the liquid should not have been held at too low temperatures or for too short periods.

Legal enactments require the provision of such efficient means of temperature control as will satisfy the requirements of the licensing authority and it must again be stressed that without this aid efficient treatment is virtually impossible. While rapid advances have taken place in the manufacture and operation of dairy instruments, there appears to be still a remarkable lack of knowledge regarding their operation, supervision and maintenance. Modern dairy plant consists of a large number of units each highly specialised in character, and all these require to be closely co-ordinated if operations are to be carried out with success. Different apparatus is required for different purposes, and no single type of control will be found satisfactory for every type of plant. Basically, however, the characteristics are the same and the control gear differs only in manufacturers' refinements such as the provision of sensitivity devices and the types of compensating units employed.

Indicating Thermometers. These instruments were originally the only means available for checking the temperatures attained in milk processing. At the present time, their primary function is to act as a check upon the recording thermometers. It is of prime importance that only high-grade apparatus should be employed for this purpose and Lambert has defined the requirements of a suitable instrument as follows :—

(*a*) The glass used in its construction should exhibit a distinctive blue streak.

(*b*) The capillary tube should be filled with nitrogen in order that the mercury column is prevented from parting.

(*c*) The glass stem should be calibrated and scales should not be marked on the metal case only.

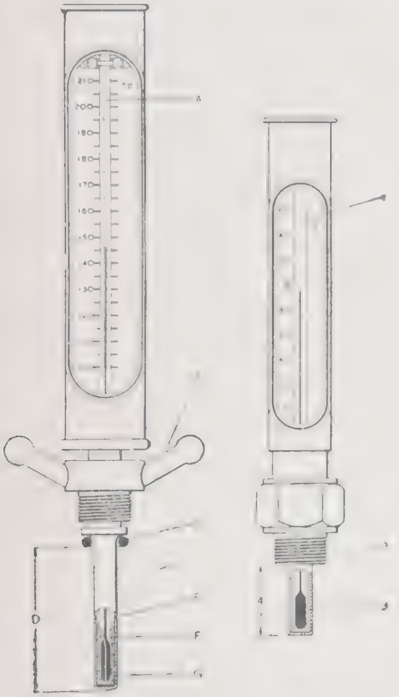
(*d*) The space between the bulb and its protective covering should be filled with some heat-conducting material to allow an adequate response to temperature changes.

(*e*) The thermometer should be sufficiently lengthy to ensure that the bulb is capable of being completely immersed in the milk.

Care must also be taken to ensure that the instrument is adequately protected from any risk of mechanical injury. Indicating thermometers should be provided to register the temperature of the milk in the pasteurising and cooling stages while others may be fitted on the hot water, cold water and refrigerant inlets.

All plants are provided with indicating thermometers, usually mercury-in-glass as standard, but these are not always correctly sited. The thermometer bulb, and this rule also applies to the bulbs of recording instruments, should invariably be immersed in accordance with the makers' instructions and positioned so that a true reading of temperature at that particular point is readily available. If not suitably placed, readings may be influenced by a variety of circumstances. Metal surfaces in close proximity to the bulb will affect them while, in addition, positioning should ensure that the flow of milk is neither checked nor delayed in its passage through the apparatus. In some plants the bulbs of these instruments are inserted in long side arms with the result that the milk swirls around them so that it is almost impossible to obtain correct temperature readings. It is important to ensure that the apparatus can be efficiently cleansed and sterilised with the thermometer bulbs in place while only stainless steel fittings should be employed, and these should be designed so that no threads which might harbour bacteria are exposed to the milk. Indicating thermometers should always be placed at points adjacent to recording instruments in order to check the working of the latter.

Errors in temperature readings may occur due to a break in mercury column while, in addition, if separate scales are employed, the relative positions of the scale *and* the glass portion of the instrument may differ. For this latter reason, graduations should invariably be engraved upon the stem so that re-positioning is facilitated. Over a period of time the glass employed is likely to contract and this contraction is much more noticeable if a cheap material is used. Such contraction cannot be entirely eliminated, and while any deviations may be noted and allowance made, the early replacement of such faulty instruments should be considered essential. Fig. 27 gives a diagrammatic comparison between a good and bad thermometer.



Note following desirable features :—

A. Calibration engraving on glass stem.
B. Provision for screwing thermometer into position by hand.
C. Hygienic sealing ring which may be sterilised.
D. Satisfactory length of pocket providing for complete immersion.
E. Groove showing minimum immersion length.
F. Blue streak indicating British "Normal" glass.
G. Metallic packing to eliminate time lag caused by an air space.

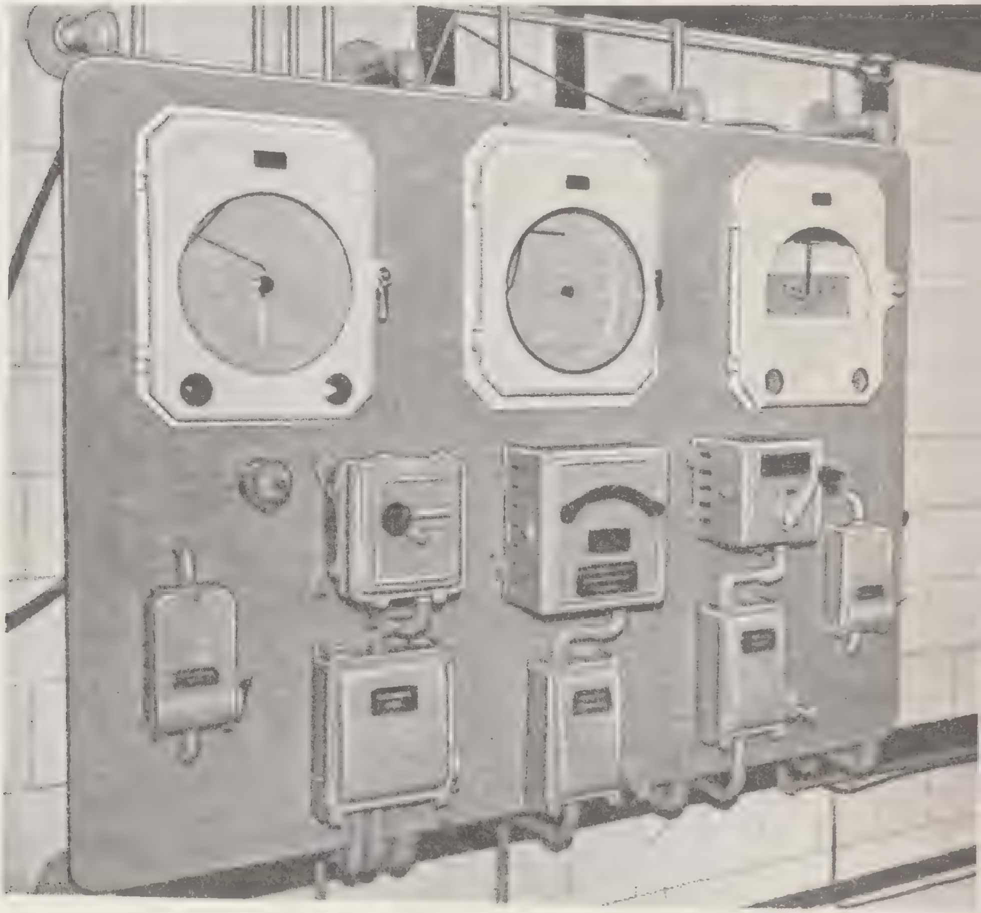
Faults frequently seen in dairies :

(1) Glass stem not engraved. Error possible through change of position of glass stem.
(2) Threaded portion in direct contact with milk—not designed for easy cleaning.
(3) Air space interfering with response of thermometer to temperature change.
(4) Insufficient immersion length.

By courtesy of Negretti and Zambra.

Fig. 27.

Correctly installed, there is no doubt that the indicating type of instrument is more reliable than any recording thermometer which, on account of its ability to be adjusted, cannot be accepted as accurate. It must be emphasised, however, that all types

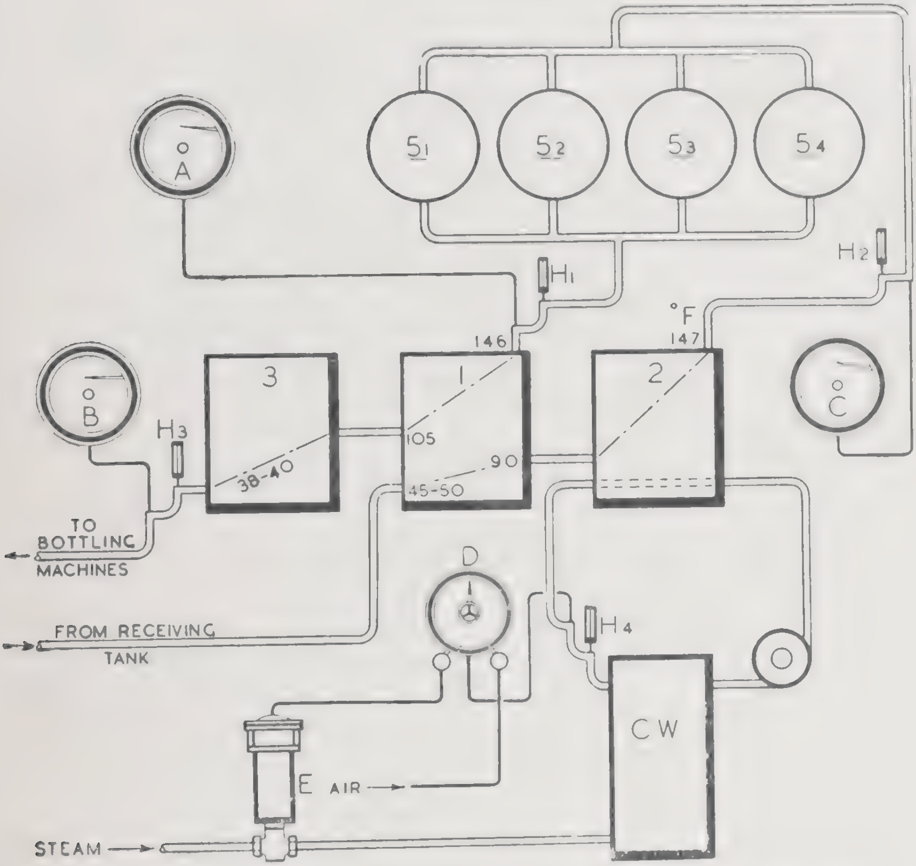


By courtesy of Cherry-Burrell Ltd.

Fig. 28. Pasteuriser centralised control panel.

require to be checked at frequent intervals in accordance with the method outlined on p. 234.

Recording Thermometers. As already mentioned, these instruments cannot be relied upon for absolute accuracy over long periods, and for this reason licensing authorities should require an indicating thermometer to be fitted immediately adjoining the bulb of the thermograph to act as a permanent check upon its action. The main function of recording thermometers is to provide a record of operations carried on in the



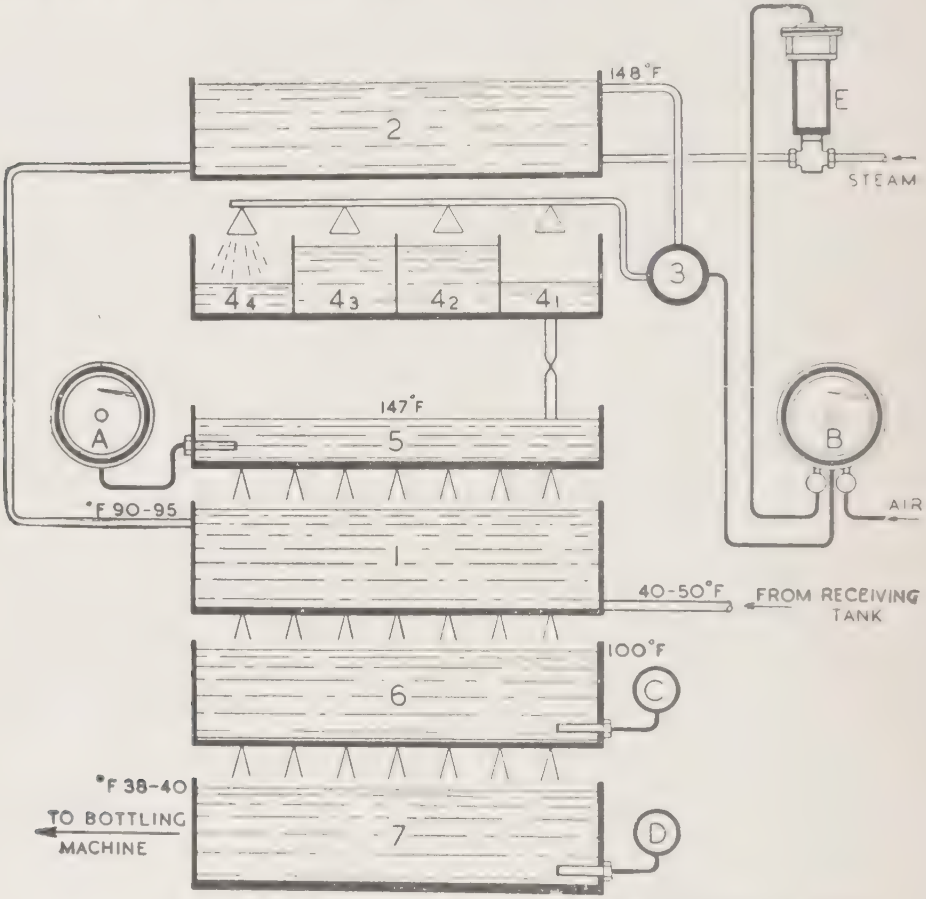
By courtesy of Negretti and Zambra.

Fig. 29.

A. Temperature recorder for milk leaving holding tanks. 5_{1-4}.
B. Temperature recorder for milk leaving cooling section (3) of heat-exchanger.
C. Temperature recorder for milk leaving heater section (2) of heat-exchanger.
D. Automatic temperature controller for circulating water.
E. Valve operated by D and controlling temperature of circulating water.
H_{1-4} Mercury-in-glass thermometers.
5_{1-4} The four compartments of the holding tanks of the retarder.
(1) Pre-heater section of heat-exchanger.
(2) Heater section of heat-exchanger.
(3) Cooler section of heat-exchanger.
C.W. Circulating water heater.

plant for subsequent inspection and this is particularly useful for the supervising official. This record should cover the entire daily working period of the plant.

The provision of at least one recording thermometer must always be insisted upon, and this should preferably be fixed at the combined outlets of the holder compartments. It is also advisable that one of these instruments should be provided to indicate the temperature of the milk as it leaves the pre-heater and also in the cold milk pipe-line to the bottling machine. In



By courtesy of Negretti and Zambra.

FIG. 30.

A. Temperature recorder for milk leaving compartments of retarder 4_{1-4}.
B. Recorder controlling regulating valve (E) governing admission of steam to heater (2).
C and D. Indicating thermometers.
(1) Pre-heater. (2) Heater. (3) Filter.
(4_1–4_4) Compartments of the retarder. (5) Collecting tank.
(6) Cooler. (7) Balance or cold milk tank.

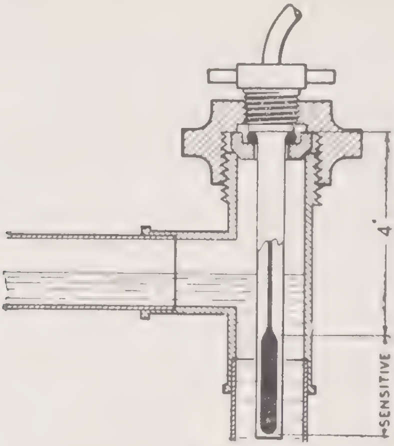
passing, it should be noted that where several recording instruments of the electrical resistance type are fitted, they may be installed at a convenient point some distance from the actual site at which the temperatures are being recorded as shown in Fig. 28. This allows them to be placed in a good light where they can be easily inspected and temperatures at all stages of treatment may be recorded in this manner. Separate recording instruments require to be provided for the independent tanks of "Batch" pasteurisers and in such cases it is important to ensure that their bulbs are sufficiently long to reach the base of the holder.

All such instruments should be kept locked in order to prevent unauthorised persons tampering with them. The key should be retained by a responsible official such as the dairy bacteriologist who should be responsible for any adjustments which are required. These adjustments are usually easy to make. In some types, the adjustment screw is fitted on the pen arm, while with others it is fitted inside the instrument and the cover plate on the face must be removed before it is accessible. It should be noted that an undesirable lag will be caused if the pen presses too hard upon the chart's surface, and if this is noticed the pen must be adjusted accordingly to correct the fault.

Fig. 29 shows the correct positioning of temperature recorders on the plate heater type of apparatus and Fig. 30 on plants which employ a tubular heater. This is extremely important. As with indicating thermometers, it is also important that recording instruments should be periodically checked for accuracy by the method outlined on p. 234.

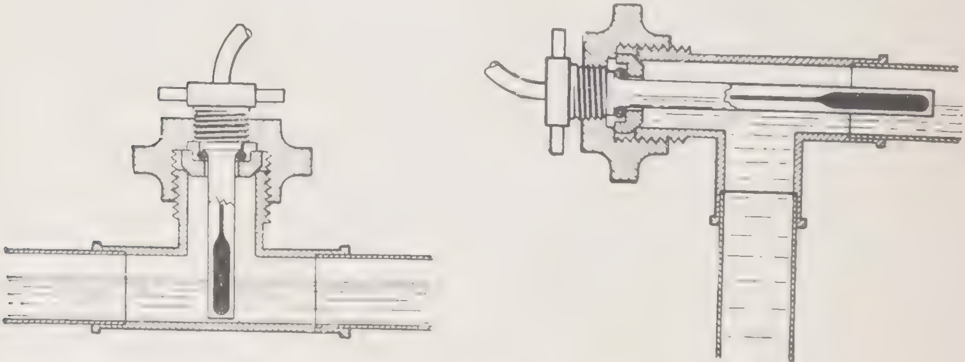
Two types of recording thermometers are employed for dairy apparatus, these being the vapour-pressure and the mercury-in-steel instruments. The *vapour-pressure type* gives a quick response to changes in temperature and possesses an increasing scale which allows wide graduations at pasteurising temperatures. The tubing is made of copper which is non-corrodible, and this also ensures a flexible connection between the instrument and its bulb. This type is reported to possess the tendency to introduce a slight error which is dependent upon barometric pressure variation on account of its inherent low internal pressure, while its accuracy is affected by any difference in level between the bulb and the instrument itself. It is usual to provide an adjustment in order to correct this fault. The pen moves rapidly and this may, on occasion, overshoot and suggest that errors in control are greater than is actually the case. The overall accuracy does not appear to be better than ± 1·5 to 2 per cent., although it is more sensitive than the type which relies upon the use of mercury.

The *mercury-in-steel instrument* possesses a speed of response two or three degrees when compared with the indicating thermometers. Such errors would be unimportant if the instrument was checked weekly by some competent person, and if more reliance was placed upon the indicating thermometer which is less likely



A

Correctly installed thermometer bulb. Note sensitive portion is completely immersed in milk.



B C

Incorrectly installed thermometer bulbs. Note that sensitive portion is not completely immersed in either case.

By courtesy of Negretti and Zambra.

FIG. 33.

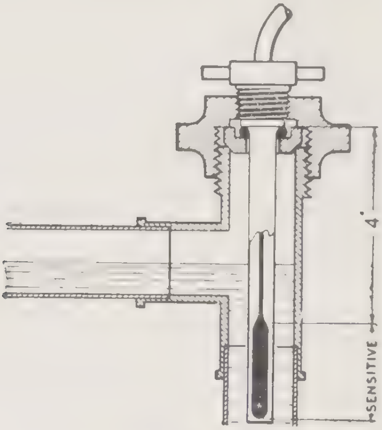
to error. With all recorders, correct immersion of the bulb is again essential. Fig. 33 illustrates the correct method of immersion and also demonstrates how these instruments may be incorrectly installed.

Charts. The charts used in recording instruments are important and it is essential that they should be printed on a sufficiently large scale so that the smallest variations in temperature and their duration may be discerned. Both time and degrees must be reasonably spaced and one-sixteenth of an inch per degree Fahrenheit is the recommended minimum standard. The important ranges of temperature are from 120° F. upwards, while the time spacing is equally important in order that the holding periods of separate tanks may be properly recorded and checked. The time spacing on some charts is so cramped that it is impossible to discover how many of the holder compartments or separate tanks have been emptied over a given period, and for this reason the time spacing should never be less than $\frac{3}{8}$ inch per half hour.

There is a tendency to record the temperature of the milk as it leaves the holder compartments and its temperature after final cooling on the same chart by means of double pens. This method cannot be recommended as charts drafted in this manner must of necessity possess a range from 30° F. to about 175° F., and, if one chart is employed for this purpose, the divisions will be every minute. It is extremely important that charts be used for recording pasteurisation temperatures only and sealed from 130° to 170° F. Heating and pasteurising temperatures may, if desired, be usefully recorded on one chart as these are within the same temperature ranges. Other records, however, require separate charts. All charts should provide for a 12-hour rotation and be printed with one degree divisions between the crucial temperatures in order to give a clear indication of the levels attained.

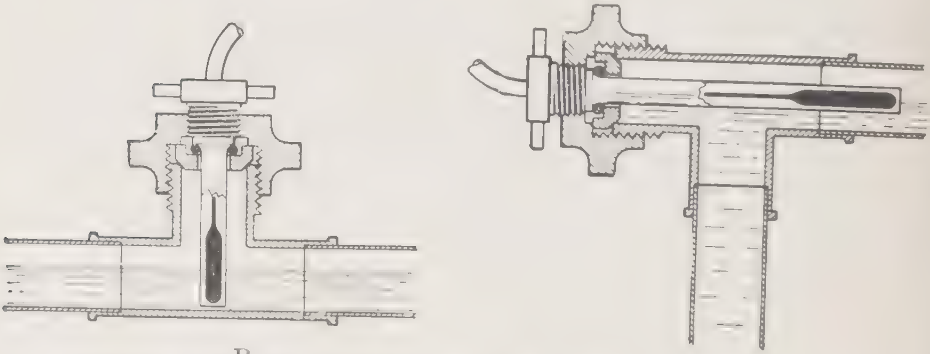
The temperature control chart illustrated in Fig. 34 demonstrates the necessity for strict control to within a fraction of a degree when processing. The upper of the two lines shows the temperature of the milk entering the holder while the lower section indicates the temperature of the liquid as it leaves the various compartments. The several drop lines show the change over from one compartment to another as each is emptied. It will be observed that there is no drop in temperature during the holding period, which is as it should be, and it is also interesting to note that the varying lengths of the drop lines shown on the chart actually illustrate the distances of the various compartments from the central control. The compartments furthest away show the longest drop lines and this demonstrates that the contents have taken slightly longer to reach the bulb of the recording thermometer which is indicating the temperature.

two or three degrees when compared with the indicating thermometers. Such errors would be unimportant if the instrument was checked weekly by some competent person, and if more reliance was placed upon the indicating thermometer which is less likely



A

Correctly installed thermometer bulb. Note sensitive portion is completely immersed in milk.



B

C

Incorrectly installed thermometer bulbs. Note that sensitive portion is not completely immersed in either case.

By courtesy of Negretti and Zambra.

Fig. 33.

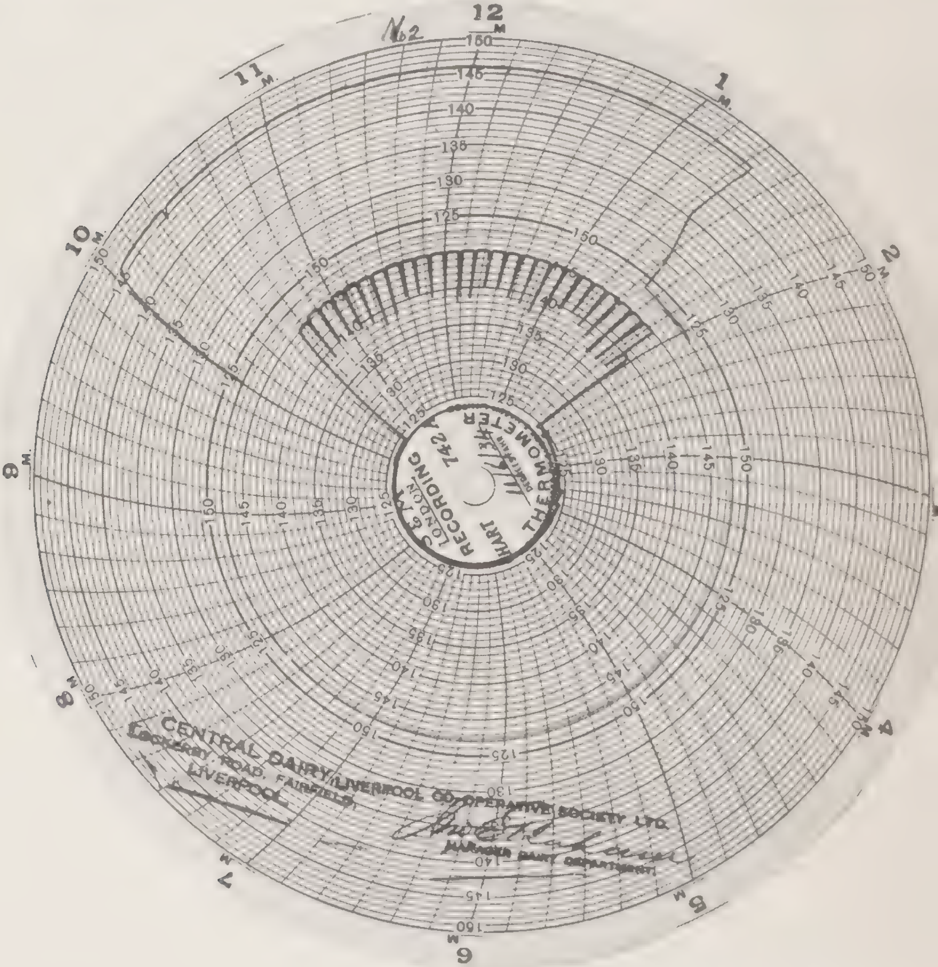
to error. With all recorders, correct immersion of the bulb is again essential. Fig. 33 illustrates the correct method of immersion and also demonstrates how these instruments may be incorrectly installed.

Charts. The charts used in recording instruments are important and it is essential that they should be printed on a sufficiently large scale so that the smallest variations in temperature and their duration may be discerned. Both time and degrees must be reasonably spaced and one-sixteenth of an inch per degree Fahrenheit is the recommended minimum standard. The important ranges of temperature are from 120° F. upwards, while the time spacing is equally important in order that the holding periods of separate tanks may be properly recorded and checked. The time spacing on some charts is so cramped that it is impossible to discover how many of the holder compartments or separate tanks have been emptied over a given period, and for this reason the time spacing should never be less than $\frac{3}{8}$ inch per half hour.

There is a tendency to record the temperature of the milk as it leaves the holder compartments and its temperature after final cooling on the same chart by means of double pens. This method cannot be recommended as charts drafted in this manner must of necessity possess a range from 30° F. to about 175° F., and, if one chart is employed for this purpose, the divisions will be every minute. It is extremely important that charts be used for recording pasteurisation temperatures only and scaled from 130° to 170° F. Heating and pasteurising temperatures may, if desired, be usefully recorded on one chart as these are within the same temperature ranges. Other records, however, require separate charts. All charts should provide for a 12-hour rotation and be printed with one degree divisions between the crucial temperatures in order to give a clear indication of the levels attained.

The temperature control chart illustrated in Fig. 34 demonstrates the necessity for strict control to within a fraction of a degree when processing. The upper of the two lines shows the temperature of the milk entering the holder while the lower section indicates the temperature of the liquid as it leaves the various compartments. The several drop lines show the change over from one compartment to another as each is emptied. It will be observed that there is no drop in temperature during the holding period, which is as it should be, and it is also interesting to note that the varying lengths of the drop lines shown on the chart actually illustrate the distances of the various compartments from the central control. The compartments furthest away show the longest drop lines and this demonstrates that the contents have taken slightly longer to reach the bulb of the recording thermometer which is indicating the temperature.

Temperature Control. Having considered the measurement temperature, it is now necessary to deal with the methods b which it is controlled. The need for accuracy in this respe cannot be doubted and large plants, in particular, make con siderable use of automatic temperature and pressure controlli



By courtesy of Cherry-Burrell Ltd.

FIG. 34. Temperature Control Chart.

apparatus. Present-day plants are normally fitted with sta dardised control equipment, often with the addition of device to increase sensitivity and valve precision, while usually the possess some form of compensating unit. These refinements a rendered necessary on account of the type of plant employe The standard equipment consists of a steam-pressure controlle for maintaining a constant pressure of steam injected into the water used for heating purposes, while an indicating temperature controller is also provided for regulating the admission of steam to the water.

A constant steam pressure is extremely important as any change in constancy will be the cause of temperature fluctuations in the heating water, the range of which will depend upon this change. For this reason, a *steam-pressure controller* is always necessary to ensure that pressure remains constant. Such controllers are almost always of the air-operated type, as by this means throttling control may be most conveniently provided. It should be noted, however, that the system best suited to any particular apparatus depends upon the design of the plant and also upon the operating conditions, no single form of controller being applicable to every type of plant. As an instance of this, when the heating medium is circulated by means of a pump, a different type of controller is required than is necessary for plants where free circulation of water is employed. This apparatus is normally fitted with connections to air supply, to regulated pressure and feed to the diaphragm valve. Most controllers function efficiently at steam pressures varying between 40 and 70 lbs. per square inch but a reducing valve should be regarded as an essential fitment with higher steam pressures or where considerable variations in such pressures are likely to occur. These valves must be adjusted so that only the minimum pressure required for maintenance of essential temperature is employed.

The *temperature controller* is an extremely important unit working in conjunction with the steam-pressure controller, and it is usually air operated, a small, self-contained compressor supplying air at a pressure between 15 to 25 lbs. per square inch. This is connected to the controller and from there to a diaphragm-control valve inserted in the steam line to the heater. If the steam pressure rises above a fixed point, this diaphragm expands and air is fed to the top of the valve which commences to close, the pressure being reduced to the required level. Alternatively, if pressure decreases, the diaphragm is deflated and air leaks from it through the instrument relay valve, an increased flow and pressure resulting. Regeneration greatly reduces the load on a plant and if this is employed, a " second-response " unit must be fitted to overcome load changes, the amount of steam required being reduced by half or even more. Under such conditions the ordinary diaphragm valve is too large and the addition of the "second-response" unit allows control to be regained without any undesirable fluctuations. Indicating and recording thermometers are, of course, essential features of all temperature controllers.

The compressor should always be located in a clean, dry position. If this is not possible, the air inlet to the apparatus should be piped to a suitable position and an air filter should always be provided. This filter is usually composed of silk waste and the medium requires to be renewed at least every six months. Clean, dry air is essential as any steam vapour entering the apparatus will cause difficulties due to an accumulation of condensed water in the working parts. The controller is adjusted to regulate, within extremely close limits, the air pressure supplied through the control valve and just sufficient steam is allowed to pass to maintain a constant temperature.

Pressure gauges are a standard fitment at the inlet to and the outlet from the instrument and these show its performance. Before any adjustments are considered necessary, the pressure of the air supply should be checked. The outlet pressure should be approximately half that of the inlet pressure which should remain steady at all times.

No temperature controller can operate efficiently unless it is correctly installed and its bulb may either be fitted in the milk outlet of the heater where the temperature is controlled by regulating the flow of air to the diaphragm valve installed in the steam line of the injector, thus providing for direct control, or it may be placed in the water section affording indirect control. The controller is set to maintain correct temperature, the instrument's sensitivity being adjusted so that the valve allows sufficient steam to flow in order that the requisite temperature may be maintained within extremely close limits.

When the plant is started up, the steam valve is held fully open, steam being injected into the water at a high rate as at that time the water temperature is low. As this temperature increases, the pressure in the instrument tube system increases, thus expanding a coil which, in turn, operates the indicating pointer and control mechanism. When the required temperature is attained, air is diverted to the diaphragm valve which immediately commences to close and reduces the amount of steam injected into the water. A " throttling " control is provided which allows just sufficient steam to flow in order to maintain the required temperature.

Maintenance. The importance of temperature-controlling instruments to both the operator and to the controlling official should never be overlooked and their correct maintenance deserves special attention. Careful handling is essential, particularly as regards the capillary tube of the temperature controller, otherwise the active life of these instruments will be considerably reduced and their accuracy decreased. If proper maintenance is provided, increased service and reliability will result, and all instruments should be invariably maintained in a scrupulously clean condition. Air strainers, moisture traps and air-receiving tanks should be blown out daily as in this manner any troubles likely to be experienced owing to dirty air valves will be considerably decreased. The oil level of the compressor needs to be carefully watched. These appliances will give years of service if properly cared for and many dairies have operated for considerable periods without any serious breakdown, owing their immunity from trouble to the fact that both plant *and* temperature controllers have always been carefully maintained. Constant servicing of such instruments by the manufacturers is an aid to lengthy, active life. Plant operators would do well to remember that they are dealing with a scientific process of great importance to the health of the community and only by careful attention to temperature can the required results be achieved.

CHAPTER VII

IN-BOTTLE PASTEURISATION

THE idea of pasteurising milk in bottles is not new, and although it has been realised for some considerable time that the liquid could be treated in this manner, this method has only become a sound hygienic proposition within the last few years. In 1908, Heineman in America, noting that beer was pasteurised in containers, experimented with milk on similar lines. Several methods were tried to attain this end but none appeared to meet with much success. In one process, bottles of the narrow-necked type were filled with cold milk and crown corked. These were submerged in cold water which was gradually heated by means of steam to a temperature of 150° F. at which level the bottles and their contents were retained for 30 minutes. Cooling was carried out by the admission of mains water at the base of the tank, replacing the hot water which overflowed to waste.

The early experimenters naturally discovered the many disadvantages of this method and difficulties arose through the type of bottle or closure employed, and owing to the imprisonment of odours and flavours due to heating milk *from cold* in tightly-sealed bottles. During the heating process, the liquid expanded and either oozed out of, or forced off, the caps from the necks of the bottles. Fibre caps, when employed, allowed the infiltration of heating or cooling water into the milk. To overcome these difficulties, special over-size bottles were devised which allowed the liquid to expand, while caps of the crown cork type were found to be essential. Unless great care was taken in treatment, there were heavy losses due to bottle breakage and the costs of production were considerably increased. A further increase in cost was due to the general practice of employing cold bottles as these required to be heated, in addition to their contents, causing additional expenditure on fuel.

It was not until after the War of 1914-18 that steps were taken in this country by Arthur G. Enock (1928) to design a plant which could be usefully employed for the treatment milk in bottles or one which overcame some of the main inherent objections, and it is only during the last fifteen years that the plant was placed upon the market as a commercial proposition. The present system is really a modification of the low-temperature method and, this being the case, the process can be carried out in conformity with statutory requirements. The chief difference between this method and the usual low-temperature process is that the milk after preheating is filled directly into hot bottles which are immediately capped. These pass to the holding chamber where they are held for the prescribed period at the correct temperature, after which cooling takes place.

While pasteurisation in bottle possesses certain marked *advantages* this method of treatment has not made much progress in this country up to the present time. It has been practised in America on a fairly large scale, but the number of distributors now using this method has fallen considerably, and very few plants are now operating on these lines either there or in this country. As with all such processes, the safety of the milk is the prime necessity. The method of treatment positively destroys all pathogenic organisms together with the greater portion of the non-pathogenic bacterial content, with the result that milk treated in this manner possesses lengthy keeping qualities and also a good cream-line. In addition, no organisms can obtain entrance to the liquid from holding devices or from coolers, or from any external sources likely to re-contaminate the milk. The bottles and their closures are heat-treated along with their contents and risks arising from unsterile bottles and caps as well as from human contamination are prevented. There is no waste of time due to filling or discharging of holding vessels, no risk of unpasteurised foam or likelihood of raw milk finding its way into holders, while the contamination of milk, already pasteurised, through faulty valves is obviated. No milk can be pasteurised twice and there is no risk of thermophilic infection. There are no differences in temperature such as may occur with bulked milk, no risk of heat loss in holders due to faulty insulation and no losses due to evaporation. Holding is commenced immediately after bottling, flavours or odours due to feeding materials are evacuated during the heating process before bottling takes place, while as the milk is held in a glass container, there is no danger of metallic contamination. Milk exhibits a better cream-line and possesses better keeping qualities than are imparted by pasteurisation in bulk. This system would be extremely useful if it could be applied to

milk at the farm immediately after production. At the presen
time, however, it could not be attempted by the producer-retaile
on account of the capital outlay required, but steps are bein
taken to provide small plants at a reasonable price. The proce
shows a great reduction in the cost of labour, water, steam and
detergents required for cleansing purposes. The time occupie
in cleansing is 75 per cent. less than that required for the mo
usual type of plant, while no subsidiary apparatus is necessar
Automatic action places the results of processing beyond th
operator's carelessness.

Before describing the various methods of treatment which hav
been devised, it is necessary to refer to the *bottles and seals* en
ployed. The aims of the designers of the apparatus to be describe
has been to employ a standard bottle as this type of container po
sesses certain commercial advantages. Compared with the narro
necked type, it is easy to clean and sterilise, takes less time
fill and the evacuation of its air content is simple. The bott
recommended and employed for some of the processes to
described is similar in height and diameter to the ordinary ty
of milk container. It possesses, however, two distinct points
difference, being of slightly larger capacity so that it may
filled with hot milk which occupies a little more space than col
while a strong rim is provided in the neck, about $\frac{3}{4}$ inch belo
the top of the bottle. This rim shows the imperial measu
level, and facilitates easy handling of the container. Allowin
a little more space above the measured milk level, the bottl
may be sealed quickly after filling with hot liquid, without wettin
either the caps or the discs. This moulding enables the custom
to see at a glance whether or not it contains the proper measur
and the disc or cap can be removed easily without risk of spillag
If the milk becomes frozen during winter, the cap is not pushe
off, while discs do not become soft or wet owing to the liqu
coming into contact with them. During cooling operations, th
moulding marks the depth to which the container is submerge
in the cooling agent.

Although a good disc may be used, the most satisfactory ty
of seal is the aluminium cap, and one which has been design
is fashioned from a square piece of foil during its attac
ment to the rim of the bottle. As this foil is pressed to fit th
round neck of the container, it is natural that it should overla

at the edges, and it is impossible for the seal to be removed by a rotating pressure of the hand and subsequently replaced. In this way it differs from many of the aluminium caps at present employed for sealing purposes, some of which do not provide a milk-tight seal, while others can be removed and replaced without damage if care is exercised in the operation. The standard bottle can be used if desired as the filling machines employed will deal with this type of container.

Milk may be treated in the container by one of two methods. It may be filled hot into bottles direct from the washing machine, these being sealed, and submerged in tanks containing water at a temperature slightly above pasteurising level. The bottles finally pass through water at different temperatures for cooling purposes. The usual method employed in this country is to fill the milk into heated bottles which are sealed and passed through a hot-air chamber, their passage occupying exactly 30 minutes.

The milk treatment routine is briefly as follows. The raw liquid after it leaves the tipping tank passes to storage, from where, by means of quantity control pumps, it is delivered through filters, and over stainless-steel milk heaters of the ventilated type, heated by internal water circulation. The quantity of liquid passing over and its temperature is automatically controlled so that the milk is raised to the pasteurising point required. This operation assists any contained gases to escape, and this action is later aided by the de-aeration of the milk when the bottles are filled by vacuum action, while it also ensures the evacuation of those odours which are only liberated at higher temperatures. This aeration and de-oxygenation prevent the destruction of ascorbic acid and preserve vitamin C. The milk is heated to 147° F., after which it gravitates through an exceedingly short jacketed pipe-line to the receiver of the vacuum-operated bottle-filling machine. This receiver is hot-water jacketed and the liquid is filled into hot sterile bottles as delivered from the washing machine. The bottles are capped, held for the requisite 30 minutes and are finally cooled.

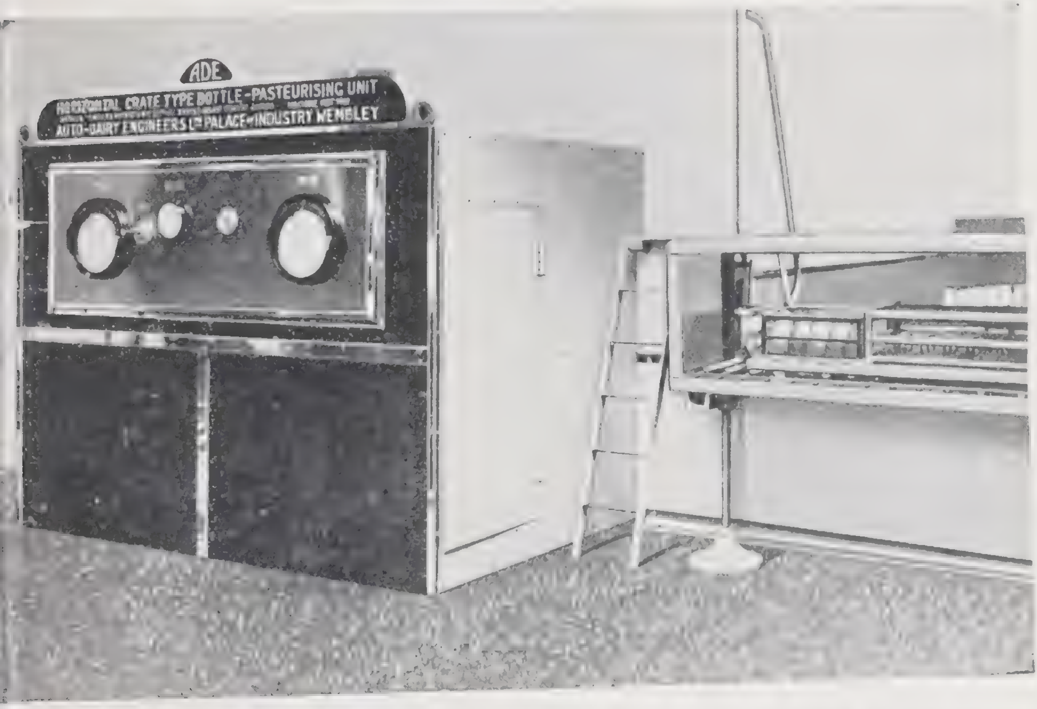
One of the first plants to be employed commercially in this country was known as the *vertical type* and this apparatus, which could handle from 400 to 5,000 gallons of milk per day, possessed a holding chamber provided with " airbells " or " domes," in each of which a single bottle was suspended during the holding period and the cooling operations which followed. Clean, sterile bottles were filled with milk at pasteurising temperature, capped and immediately delivered by means of a heated conveyor across the front of the apparatus. The "airbells" travelled upwards and downwards through the hot air holding chamber, this heating agent maintaining the caps or discs in a dry condition. In this chamber milk was held at a temperature of 147° F. for 30 minutes.

At the expiration of the holding period, the bottles passed through a chamber which had circulations of warm, main and refrigerated waters, being gradually cooled to between 40° to 45° F. While the "domes" were submerged during cooling operations, the manufacturers claimed that the discs or caps could not be affected by the cooling agent as it was not possible for the water to rise higher than some $\frac{3}{4}$ inch below the bottle lip on account of the air pressure inside each "dome."

After traversing several cooling chambers, the containers were delivered at the front of the machine from where the operator removed them. One-man operation was thus assured although, if thought desirable, the machine could be fed and delivery effected at opposite ends.

The apparatus now described represented a great advance on early attempts to solve the problem of pasteurisation in bottle although the method still possessed certain inherent disadvantages. One difficulty experienced was the slight fall in temperature between the heating and holding processes owing to milk cooling in the balance tank of the bottle filler. This was remedied in later models by jacketing this tank of the bottle-filling machine and enclosing the bottle conveyors by means of heated shrouds. Cooling also occurred owing to the delay which occurred between sealing and fitting bottles into the "airbells" and their entry into the holding chamber. The cooling of empty bottles which may not have been at a suitable temperature when filled and the amount of handling required, each bottle having to be fitted into a separate "airbell," were further difficulties. In addition, no guaranteed method of checking the milk temperature with any certainty during the holding period existed, excepting the thermograph of the holding chamber and an occasional test, made by placing a small thermograph into a traversing bottle. There was also no guarantee that the pressure in the "domes" was sufficient to ensure a water seal suitably effective to prevent access of the cooling agent, with the consequent destruction of any cardboard seals employed. This latter difficulty, of course, only occurred at infrequent intervals.

It was natural, perhaps, for critics of the system to pick upon what may be termed theoretical weaknesses, but to meet such criticisms, radical alterations have been incorporated in the most recent type of plant to ensure that any such difficulties are obviated. This modern plant, known as the *horizontal type*, is entirely at variance with customary methods of milk treatment. It is designed to deal with any quantity of milk up to 30,000 gallons per day, the ideal sequence of treatment being straight-line working. Briefly, it may be stated that clean, sterile bottles are filled with milk at pasteurising temperature and are capped and placed in clean, warm crates. The crated bottles then traverse the holding chamber, their passage occupying exactly 30 minutes

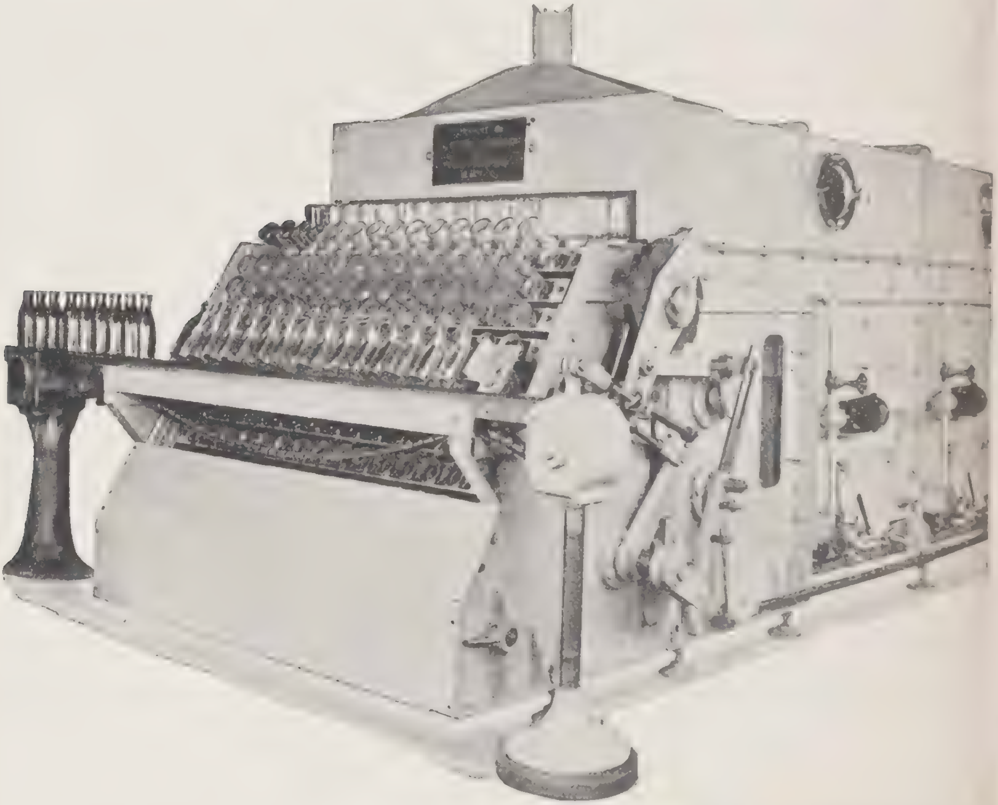

ADE
HORIZONTAL CRATE TYPE BOTTLE-PASTEURISING UNIT
AUTO-DAIRY ENGINEERS Ltd PALACE of INDUSTRY WEMBLEY

By courtesy of Auto-Dairy Engineers Ltd.

Fig. 35. "A.D.E." In-bottle pasteurising plant. (Horizontal type showing control panel and delivery of bottles into holding chamber.)

The crates, with their contents, are then cooled and passed to refrigerated storage until required for delivery.

The "*A.D.E. Straighton*" washing machine, illustrated in Fig. 36, is the normal complement of the in-bottle pasteuriser and is a unit designed to deal with from 800 to 6,000 bottles per hour. This apparatus provides a maximum rinsing time during treatment. The bottles are pre-rinsed and then washed fifteen times with detergent and water washes of steadily rising temperatures. This ensures the complete removal of detergent from each bottle and minimises breakages due to temperature changes. Ample drainage spaces are provided between washes, while each wash tank has a separate pump and filter through which all liquids must pass on their way to the jets. The spray pipes are fitted with special atomisers which give a high powered



By courtesy of Auto-Dairy Engineers Ltd.

FIG. 36. "A.D.E. Straighton" bottle washer (delivery end showing heat control side).

rinse, the outside surfaces of the bottles also receiving adequate treatment. The wash tanks, which can be quickly drained, are fitted with self-acting thermostats for the accurate control of the various temperatures. Gauge tubes are provided to show the height of liquid in each tank together with plate glass inspection windows in the sides of the apparatus. Each of the larger machines is fitted with an automatic feeder for strong detergent solution allowing uniform strength to be maintained at all times. On leaving the detergent compartments, the bottles are washed several times with soft washes at gradually increasing temperatures, being finally dried with superheated steam at a temperature between 350° and 400° F. The apparatus is entirely automatic in action, and is designed so that bottle-filling follows washing operations, a hot bottle being supplied to receive hot milk prior to processing. A cold bottle may be delivered if required, in which case the final jets are connected to luke-warm and finally cold waters to reduce bottle temperatures before filling takes place.

While bottle washing is proceeding, the raw milk undergoes its preliminary treatment. On receipt at the plant it is tipped into a reception tank, from which it is transferred to storage. By gravitation, the milk passes over a stainless-steel heater where its temperature is raised by means of internal water circulation, although any other type of preheater may be employed if desired. The quantity of milk passing over and its temperature are automatically controlled so that the milk temperature is raised to the point requisite for the successful removal of slime and sediment. Pre-warming assists gases and odours to escape and this action is helped through aeration of the milk by centrifugal action. The second heating to pasteurisation temperature assists in the escape of those odours which are only liberated at higher temperature levels. In this manner, objections which have been raised sometimes regarding bad flavours present in milk pasteurised in bottle are effectively overcome. The preheater, milk cleaner or filter are installed above the normal plant level.

After clarification, the milk is delivered to a final heater, which raises its temperature to 147° F., although it is not essential that such an apparatus should be employed. After the final heating process, the liquid gravitates through an extremely short pipe-line to a balancing tank placed over the vacuum-operated bottle-filling machine. This tank is hot-water jacketed to maintain the temperature, and the milk is immediately filled into hot bottles coming from the washing machine.

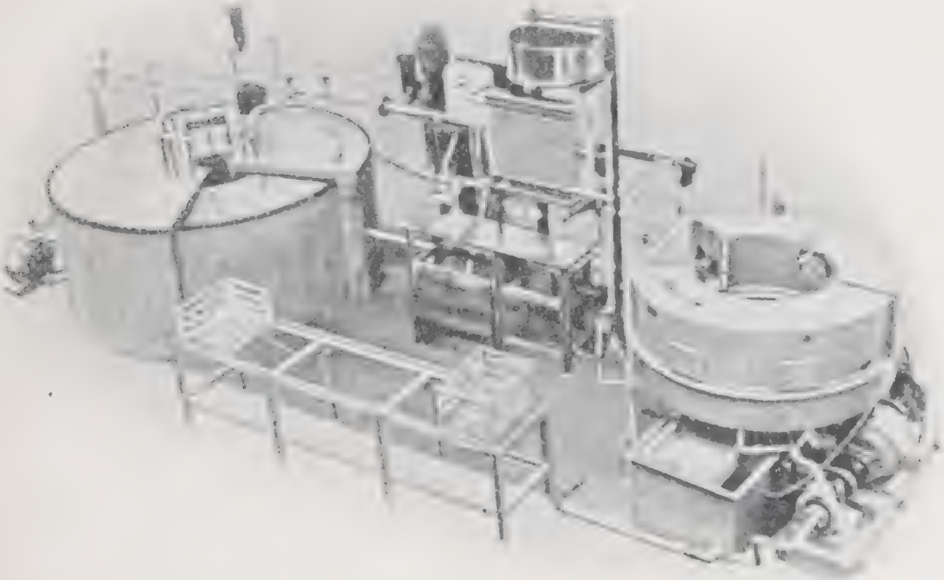
The empty bottles coming from the washer, still at a temperature of 150° F., pass to the bottling machine, being filled with milk to the level of the external moulding. Any size of bottle can be dealt with if desired. The crates arrive in clean, warm condition from the crate washer and, after sealing by the capping machine adjoining the filler, the bottles travel on a heated conveyor to a point where they are crated. Gravitation filling machines may be supplied in lieu of the vacuum type if desired.

The crates with their contents travel a few feet to the holding chamber which is constructed in the form of a long tunnel. Each crate of bottles traverses this chamber in exactly 30 minutes, hot air being employed for heating purposes and a temperature of 147° F. is maintained throughout its entire length. Efficient temperature control, both of the direct-reading and recording types, are provided on an instrument panel in front of the apparatus and at all essential points. Adequate openings are provided to facilitate the removal of sample bottles so that milk temperatures during the holding period may be checked. In practice, maximum and minimum thermometers may be inserted in test bottles as they enter the holding chamber, the temperature drop being usually about one-half to one degree during the journey.

Cooling is carried out entirely by means of water. The crates with their contents enter a long narrow tank and pass through the cooling medium on chain conveyors. Each bottle is submerged to milk level, leaving a sufficient portion of the container above the water level to prevent any of the cooling agent gaining entrance. The water flows in the opposite direction to that of the crates and their contents, ensuring a complete interchange of heat, four stages of cooling down to 38° F. being provided.

Any damage to bottles is prevented by their gradual passage through water in varying degrees of temperature, the whole cooling process occupying approximately half an hour. Critics have stated that this prolonged treatment prevents the plant complying with statutory requirements, which state that milk, after pasteurisation, should be *immediately* cooled. The enactments, however, do not say that milk shall be *rapidly* cooled, and, although immediate cooling is mentioned, it must be remembered that the original legislation was drafted before the advent of "in-bottle" pasteurisation and has, so far as the cooling of pasteurised milk is concerned, remained in its original form since drafting. The immediate cooling of milk exposed to the dangers of re-contamination is no doubt essential, but when enclosed in the glass container in which it has been processed, such immediate cooling is not so important.

In the United States of America, Ayers and Johnson have shown that there is no great increase in the numbers of bacteria present if the cooling process occupies as much as 5 hours when compared with milk cooled in a much shorter time. This is stated to be due to the influence of pasteurising temperatures upon bacteria. Those surviving the process are temporarily weakened and require some time to recover their natural vitality. It should be emphasised that rapid cooling does not increase the destructive effect of pasteurisation.



By courtesy of Auto-Dairy Engineers Ltd.

FIG. 37. "A.D.E." rotary in-bottle pasteuriser.

In order to obviate criticisms that the small distributor has been overlooked, a smaller plant for pasteurisation in bottle, employing the *rotary principle*, has been designed. This apparatus will deal with from 50 to 400 gallons of milk per day. A rotary washer delivers clean, hot sterile bottles to be filled with preheated milk at a temperature of 146° F. The preheater is similar to an open surface cooler, constructed of stainless steel and provided with tight-fitting covers. The bottles are capped with aluminium seals and then placed in the rotary pasteuriser, traversing the holding chamber in exactly 30 minutes and being held at the requisite temperature. After processing is completed and while still in the rotary machine, the bottles are cooled, first with warm water, afterwards with cold water and finally with chilled water, which circulates over refrigerating coils situated in the base of the apparatus. The bottles return to their original starting point where they are withdrawn, crated, and removed to cold store. The cool compartment is automatically re-heated for the next supply of bottles to be dealt with.

Another apparatus, by which milk may be successfully pasteurised in the bottle, works on rather different lines. Hot bottles of the normal type, straight from the washing machine, are filled with preheated milk and sealed with crown corks. These are automatically loaded into the machine and pass to the holding tank containing water maintained at a temperature of 146° to 147° F., which is situated in the base of the apparatus. Time and temperature are maintained during the passage of the containers through this section, and when treatment is completed they pass to the cooling section of the apparatus. Here they are cooled at varying temperatures down to 60° F. The water in the cooling tanks is the overflow from the cooling sprays and the bottles are carried against the flow of cooling agent in their progress through the tank. A final cooling down to a temperature of 35° F. is given by means of water sprays, the final stage being refrigerated water. In all, eleven stages of cooling are given; the crown corks form a perfect seal, preventing the escape of milk and the entrance of cooling water into the bottles.

The advent of the high-temperature short-time process has caused preliminary trials to be made with a view to applying this process to the treatment of milk in bottles. Details of the present position are set out on page 161.

Probably the most serious objection which can be raised to the "in-bottle" process is the cost of plant and its subsidiaries which is primarily higher than a plant of the normal low-temperature type. This cost is offset, however, by the benefits which accrue. Commercial advantages include low cost of operation, simplicity, low labour costs and automatic action which places the results of processing beyond the operator's carelessness. Loss of milk due to evaporation and to adhesion on internal surfaces of the plant are entirely obviated, while any subsidiary apparatus now employed can be incorporated in the lay-out if desired. In addition, souring is eliminated, loss from bottle breakages is extremely low due to hot milk being filled into hot bottles, and the consumer satisfied.

From the public health viewpoint, the one great advantage, and one which outweighs all others, is the freedom of milk after treatment from any possibility of re-contamination either from the apparatus, the atmosphere, from flies or by human agency. One must always remember that many types of disease-producing organisms are not in the milk as it leaves the cow, but obtain entrance between production and bottling. Pasteurisation in bottle should be regarded as the ideal method of treatment and one which is worthy to be more widely practised.

CHAPTER VIII

THE SHORT-TIME PROCESS

OWING to the fact that the high-temperature short-time process of pasteurisation possesses certain commercial and economic advantages, innumerable experiments have been made in order to find a system of treating milk in this manner which would render it safe from a public health viewpoint and which would also be commercially successful. Although up to a few years ago the low-temperature system of treatment was favoured in official circles, it is probable that the slow development of this method was due to the condemnation of any treatment which differed from the conventional holder process. While the need for a relatively complicated system of automatic temperature controls and other mechanical devices such as flow-diversion mechanisms made both plant operators and public health authorities reluctant to adopt this system, one must now admit that the modern short-time method can, following the conclusion of numerous experiments which have been made in both this country and abroad, be safely recommended as a standard system of milk treatment. So much so that in 1941, the Minister of Health issued new Provisional Regulations known as the Milk (Special Designation) Regulations, 1941, which dealt with the production of milk under the designation "Pasteurised." These Regulations permitted the employment of the short-time method, always provided that milk is retained at a temperature of not less than 162° F. for at least 15 seconds, that the apparatus is fitted with full thermostatic control and that a suitable device to divert the flow of any milk which has not been properly held is provided. The provisions as to temperature control are important as they serve to distinguish this process from its forerunner, "Flash" pasteurisation, by which milk was heated excessively with great fluctuations in temperatures.

Although the temperature and time limit specified must be strictly adhered to, scientifically any temperature above 140° F. with varying periods of heating would give the same result, namely, the destruction of pathogenic organisms in milk. For instance, milk could be held if desired for four to five seconds at 175° F., and the same result could be obtained. One difficulty, however, would be experienced with an extremely short retarding period. All thermometers possess a certain " lag," and to employ such high temperatures for very short periods would require temperature controllers and flow-diversion devices which possessed an extremely rapid response, much speedier than is to be obtained by present-day apparatus of the normal commercial type. It is probable that the period of 15 seconds was chosen as one which would enable standard thermometric apparatus to respond to temperature changes which might otherwise be missed if shorter retarding periods at higher temperatures were employed.

This most revolutionary change enables the distributor to pasteurise milk more quickly in a plant which is less bulky, requires less cleaning, is lower in capital cost and which is able to provide the public with a safe milk, always provided that it is properly used and maintained. As a result, many of the large producers have ceased to operate low-temperature apparatus and practically all new plants designed to handle large quantities of milk are of the high-temperature type. It must be emphasised, however, that with the small margin of safety provided, pasteurisation must achieve much greater precision than was formerly required or considered necessary with lower temperatures and longer holding periods. Nor must it be forgotten that the Regulations are still " Provisional " at the present time and it would be a great pity if the employment of unsuitable plant or methods for treating milk prevented their future permanency. Indeed, there is no doubt that the short-time process has come to stay if operated properly with suitable apparatus, and it is quite likely that when its employment is confirmed, after an extended trial period, it may well oust other accepted methods from their former pre-eminence.

In view of this radical alteration in the official viewpoint, it is necessary to consider the various short-time methods which have been employed previously in order to discover how and in what manner this present method has been evolved. The forerunners of the present system were " *Flash* " *pasteurisation* and the " *Continuous-flow* " *process.* These two processes, while capable of materially reducing the bacterial content of milk treated by their agency, did not provide any guarantee that the product was free from pathogenic organisms. Scientific and accurate control presented considerable difficulty at that time and these methods, which are more fully described later in this volume, are of interest only as forerunners of the present process. Public health authorities have always disliked the principles governing the "Flash" and "Continuous-flow" methods so that their employment for treating milk to comply with the legal enactments can never be permitted.

Although the methods mentioned above have received universal condemnation from all sanitarians on account of the apparent impossibility of devising proper scientific and accurate methods of control, the development of such apparatus together with more reliable and sensitive control devices, has altered the attitude of the Ministry of Health towards the short-time process. While this is accepted, it must be added that the issue of the Regulations to cover this method of treatment was no doubt primarily due to a desire to procure economies in fuel, labour and materials in many established processing plants, and to obtain a smaller, more readily-made plant with a view to the wider employment of pasteurisation.

Two modifications of the methods so universally condemned, which are of comparative recent development, claim to possess the advantages of simplicity and economy without any of the disadvantages so previously apparent. The systems are the *High-Temperature Short-Time* process and *Stassanisation*.

(1) **The High-Temperature Short-Time Process.** There are certain obvious disadvantages to the low-temperature method which are held to render this process uneconomical from the distributor's viewpoint. Such plants, in order to provide for continuous processing, need considerable space for installation, particularly if they are required to treat large quantities of milk, while the cost of their efficient operation, cleansing and maintenance is high. The volume of in-going and out-going milk requires to be balanced, while the length of run in large plants has, in innumerable instances, to be considerably reduced on account of the growth of thermophilic organisms, a great deal of time being wasted when the plant is closed down in this compulsory fashion for cleansing operations. Attempts therefore have been made to elaborate a system which eliminates the disadvantages while, at the same time, ensures the efficient treatment of raw milk.

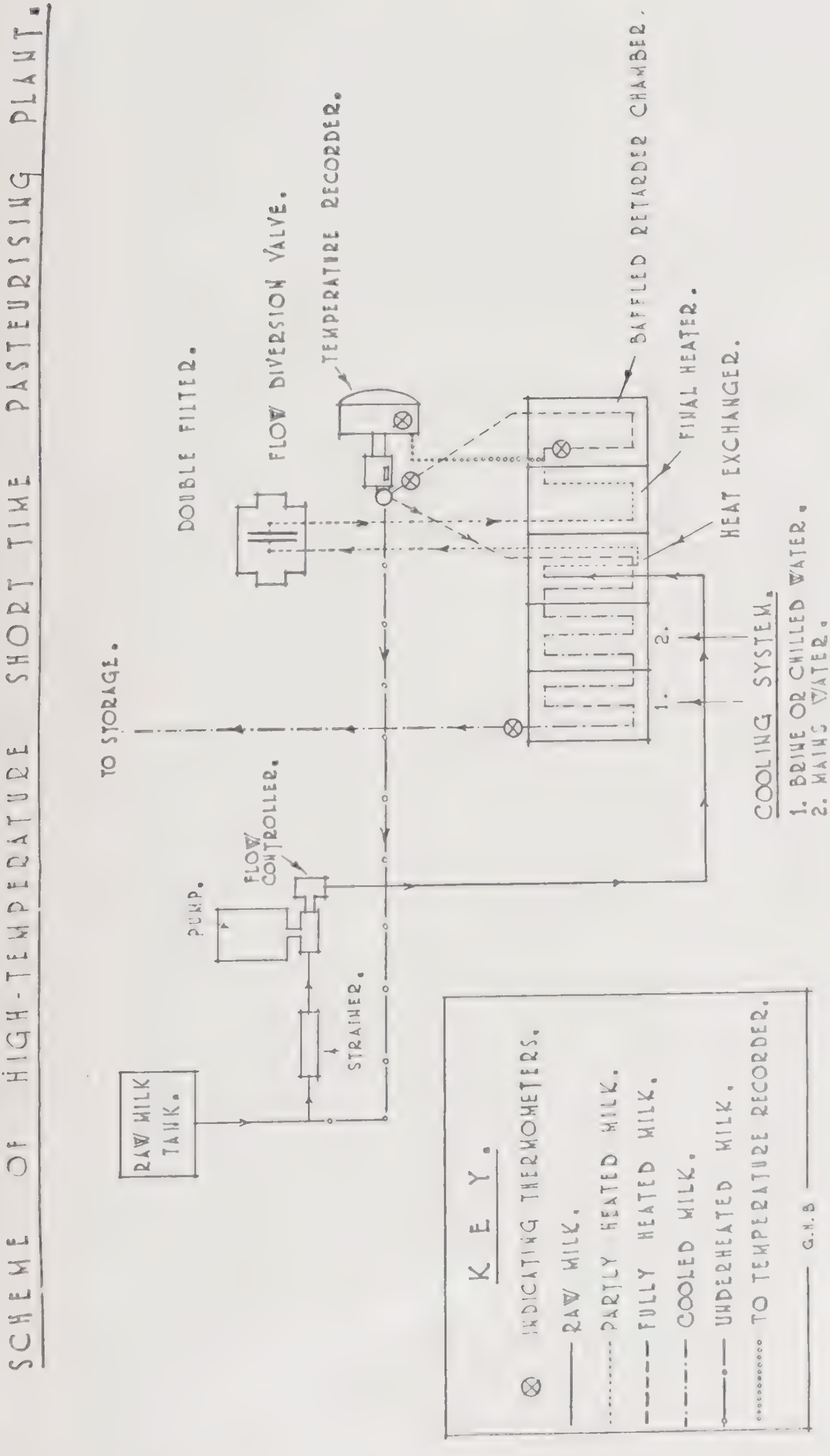

SCHEME OF HIGH-TEMPERATURE SHORT TIME PASTEURISING PLANT.
RAW MILK TANK.
STRAINER.
PUMP.
FLOW CONTROLLER.
TO STORAGE.
DOUBLE FILTER.
FLOW DIVERSION VALVE.
TEMPERATURE RECORDER.
BAFFLED RETARDER CHAMBER.
FINAL HEATER.
HEAT EXCHANGER.
1.
2.
COOLING SYSTEM.
1. BRINE OR CHILLED WATER.
2. MAINS WATER.
KEY.
⊗ INDICATING THERMOMETERS.
RAW MILK.
PARTLY HEATED MILK.
FULLY HEATED MILK.
COOLED MILK.
UNDERHEATED MILK.
TO TEMPERATURE RECORDER.
G.H.B

Fig. 38.

The old "Flash" method of treatment, condemned in 1923, was quick but uncertain, and experiments by various bodies, both in this country and abroad, have been carried on for some considerable time with a modified form of this process. The Aluminium Plant and Vessel Company were among the pioneers and their experiments have achieved considerable success. At a temperature of between 160° to 162° F., with a holding period of from 12 to 20 seconds, it was found that all pathogenic bacteria contained in milk were destroyed although it should be noted that these conditions provided too narrow a margin of safety. Certain additional *advantages* were also claimed. As it was continuous in action, there was no waiting for processing to be completed and milk could be bottled within a few minutes of entering the apparatus. No balancing of in-going and out-going milk was needed, while the apparatus occupied only a fraction of the floor space required for low-temperature plants of similar capacity. Holding vats and separate coolers were unnecessary, while all inter-connecting pipelines and balance tanks were not required. The evidence available has shown that there appears to be much less likelihood of thermophilic growth during long runs, as the higher temperature attained is not favourable to their development, always provided that the plant is not employed in treating milk which possesses a high bacterial content. The apparatus is easily cleansed, labour can be more effectively utilised, sterilisation is simply carried out by pumping hot water and steam through the system, while there is a considerable saving in running expenses, with economy in the use of fuel and water.

The automatic devices now devised give positive control of processing and the cost is no greater than that of the usual type of holding plant. The apparatus is usually designed on the lines of a heat-exchanger, the capacity being normally increased by the addition of further sections. This type of equipment is eminently suitable for regeneration, as the out-going hot milk is quickly available for increasing the temperature of cold milk entering the apparatus. With the holder system, hot milk cannot be used for regenerative purposes until fully 30 minutes have elapsed. It would appear, therefore, that this method of treatment has deserved the serious consideration which it has received, if only from the economic standpoint.

There is, however, the public health aspect of the problem, the destruction of harmful bacteria, to be considered. Experiments are now sufficiently advanced to enable it to be stated definitely that in this respect, the short-time process is quite as satisfactory as the previous officially-accepted method of pasteurising milk. It has been demonstrated that all pathogenic organisms likely to be found in milk are killed at a temperature of 160° F. for 15 seconds. The Department of Health of the State of Pennsylvania, U.S.A., appointed a Committee to investigate this type of apparatus. This Committee proved that, of 152 guinea-pigs injected with milk treated in this manner and previously inoculated with tubercle bacilli, none developed tuberculosis. Guinea-pigs inoculated with infected raw milk to which had been previously added 7·5 to 9 million tubercle bacilli per millilitre, contracted the infection and all died. Similar tests were made with milk infected with *hæmolytic streptococci*. Prior to treatment, the milk contained 4·6 to 8·3 millions of the latter organisms per millilitre, but after treatment, streptococci were absent in the 30 tests made. In addition, coliform organisms were not discovered in 10 millilitres of the pasteurised product. Experiments on similar lines have been carried out by the National Institute for Research in Dairying, Reading, during which virulent tubercle bacilli and pathogenic streptococci were added to milk in large numbers. None were discovered in the processed liquid by means of animal inoculation or by other methods. Experiments in which milk naturally infected with tubercle bacilli was employed also gave negative results.

The great test for efficiency of all pasteurising processes is the destruction of the enzyme phosphatase present in all raw milk, Kay and Neave having demonstrated that all common pathogenic organisms likely to be present are destroyed more quickly at the temperatures employed than is this enzyme. Experiments have shown that milk treated by this method of processing, properly carried out, is uniformly devoid of phosphatase as shown by the test (see p. 275). It is possible, however, to heat milk so quickly up to 162° F. that, even with a holding period of 15 seconds, phosphatase tests may be positive, and this test should not be solely relied upon as affording proof of the efficiency of the process.

Various experiments regarding non-pathogenic organisms have been carried out and show that the bacterial content per millilitre of milk after treatment by this method may be slightly *higher* than that of milk to which the normal holding process has been applied. In this connection, it should be remembered that the process is continuous, milk being drawn continually from the tipping tank to the plant without previous bulking. Under such circumstances a single sample may be representative only of the milk of a single farm, the bacterial content of which may vary considerably. In countries such as the United States of America, where this system has been used for some considerable time, raw milk, prior to processing, generally possesses a low bacterial content. Experiments have demonstrated that such milk is essential if this form of treatment is to be successfully applied. In a country where all milk treated possesses a low initial bacterial content, the method is entirely satisfactory, as in such instances pasteurisation is only required to prolong the keeping quality and to destroy any pathogens which may be present. It may be that raw milk, at certain times, contains organisms not readily destroyed by this method although the higher counts may be due to fluctuations in the operation of the plant employed. As various experimenters have invariably pointed out, this type of plant has to operate with an exceedingly small safety margin which is guarded by mechanical safeguards, and it is quite possible that this margin is occasionally overstepped through errors on the operator's part, with the result that higher counts occur than would be the case if the milk had been treated by the holder method, in which a greater margin for error is allowed. Such increases as do occur are not sufficient to warrant the prohibition of this method of processing for designated pasteurised milk.

From the public health point of view, no method of treatment can be considered satisfactory if the nutritive value of milk is impaired. Investigations on these lines carried out up to the present time, including reports from the Continent and the United States of America on milk treated by this method, imply that no difference in food value can be detected when such milk is compared with that which has been treated by the low-temperature method. Further inquiries into this matter are, of course, essential but there is little doubt that it will be found that the liquid is not radically altered. There appears to be no alteration in the taste when treated in this manner, nor does the process affect either the colour or odour. The importance of a satisfactory cream-line must not be overlooked, the customer demanding this evidence of quality in milk. From a commercial point of view the cream-line will be little damaged if strict care is taken to work within the normal limits of temperature. Experiments have proved that the more rapid the rate of heating to pasteurising temperature the less is the effect on cream-line and probably on other nutritive properties of milk. The loss of cream volume becomes noticeable if the temperature employed is 163° F. and if higher temperatures are used this loss becomes more marked.

Although thermophilic organisms do not appear to develop during processing, the plant must be efficiently cleansed and sterilised, while it is imperative that the first flow of partially pasteurised milk should be drawn off before it reaches the cooling section. If this procedure is overlooked, an infection of thermophiles may occur at this point. Short-time pasteurisers can be readily dismantled for inspection purposes and for cleansing after each run and this is a strong recommendation for their employment. Thermoduric organisms are not destroyed by this method of treatment and may be a source of trouble if any attempt is made to treat milk containing large numbers of such bacteria.

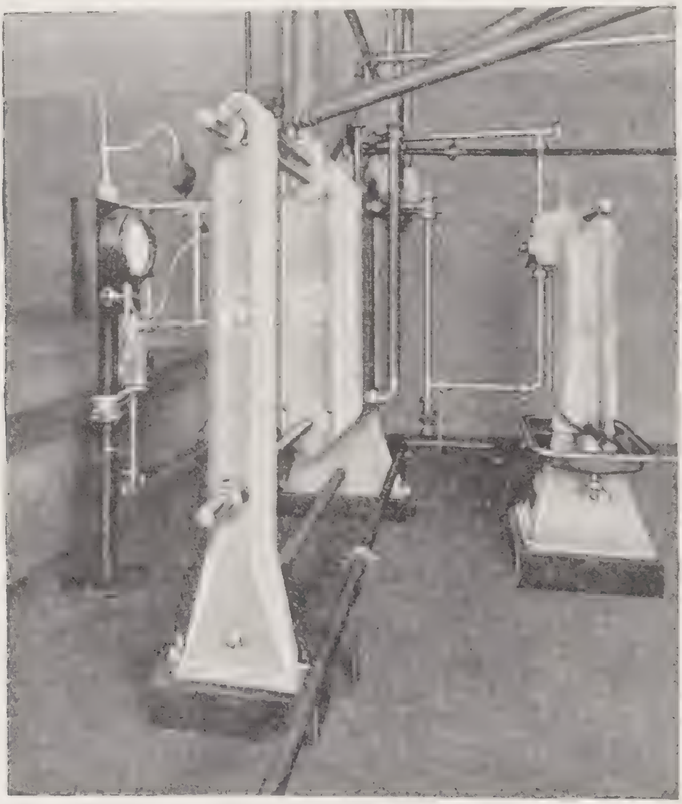
Several types of plant may be employed for treating milk by the short-time process. The *prime essentials* for any type may be taken as an adequate heating surface in the heat-exchanger, a correct milk-to-water circulation ratio, sensitive and accurate temperature controlling devices, a constant speed pump for circulating the milk and an accurate flow-diversion device. In accordance with the Regulations made by the Minister of Health under the Food and Drugs Act, 1938, the following conditions must be complied with :—

(*a*) "The milk shall be retained at a temperature of not less than 162° F. for at least fifteen seconds and be immediately cooled to a temperature of not more than 55° F." *and*

(*b*) "Such indicating thermometers and recording thermometers as the licensing authority shall consider requisite shall be inserted in suitable places in the apparatus used for pasteurising during the whole of the pasteurising process, and the apparatus shall be thermostatically controlled and be provided with a device which shall automatically divert the flow of milk which has not been retained at a temperature of not less than 162° F. for at least fifteen seconds. The type of apparatus

> and thermometers used and the methods employed shall be such as are satisfactory to the licensing authority."

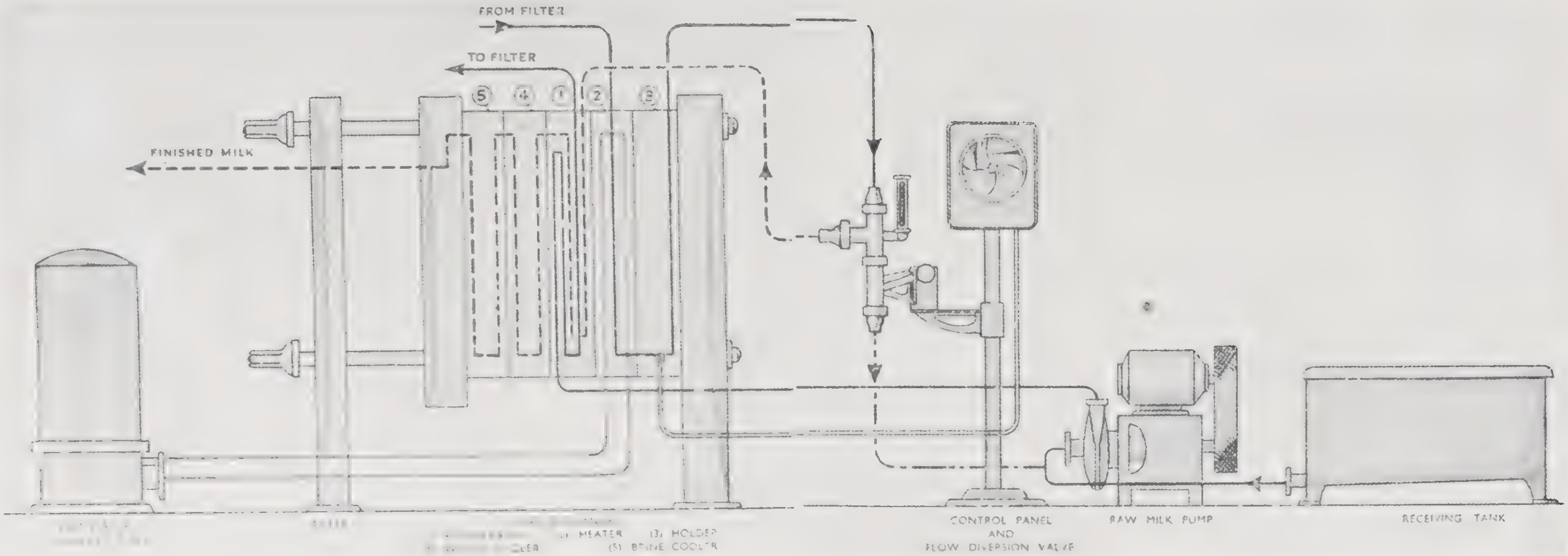
The milk must therefore receive a primary heating to at least 163° F. if the final temperature is not to fall below the limit allowed. It must be remembered that damage to cream-line and the chemical constituents of milk progressively increases as the temperature is raised above this limit, and for this reason an upper limit of temperature ought to have been fixed, above which it would be illegal to heat the liquid during treatment by this process. Failure to fix such a limit will result in many instances in the nutritional value of milk being impaired and may lead to carelessness on the part of the operator.



By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 39. A.P.V. Short-time pasteurising apparatus.

The *A.P.V. Short-time Pasteuriser* shown in Fig. 39 consists of a four-section standard plate heat-exchanger similar to that described on pp. 62 and 66, with the addition of a special



By courtesy of the Aluminium Plant and Vessel Co. Ltd.

Fig. 40. A.P.V. short-time pasteurisation (flow diagram).

holding section (see Fig. 41). The Paraflow principle is employed in the latest plants and a continuous filter is incorporated in the apparatus shown in Fig. 12, while a flow diagram is set out in Fig. 40. Capacities range from 110 gallons per hour upwards, according to the number of plates employed. The

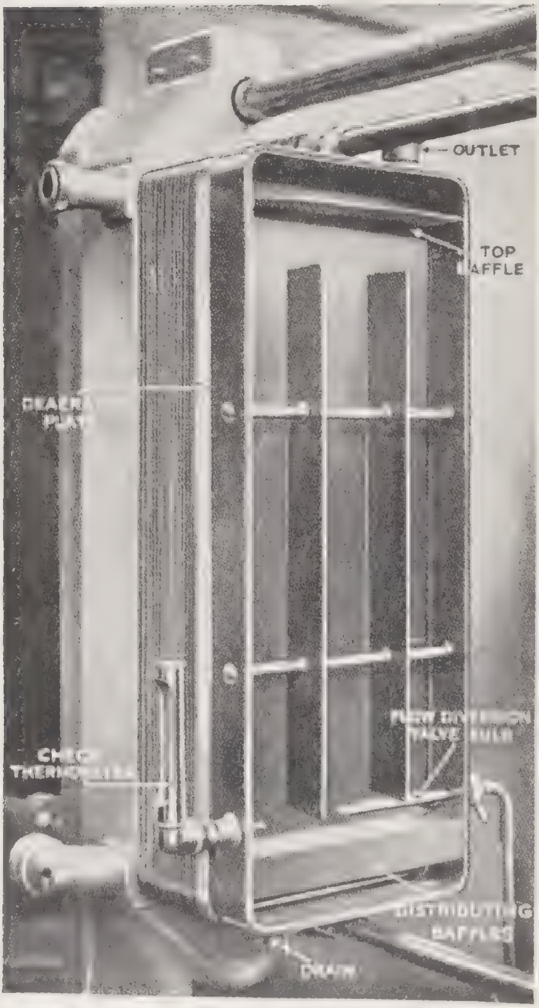


Fig. 41. A.P.V. Short-time holding section.

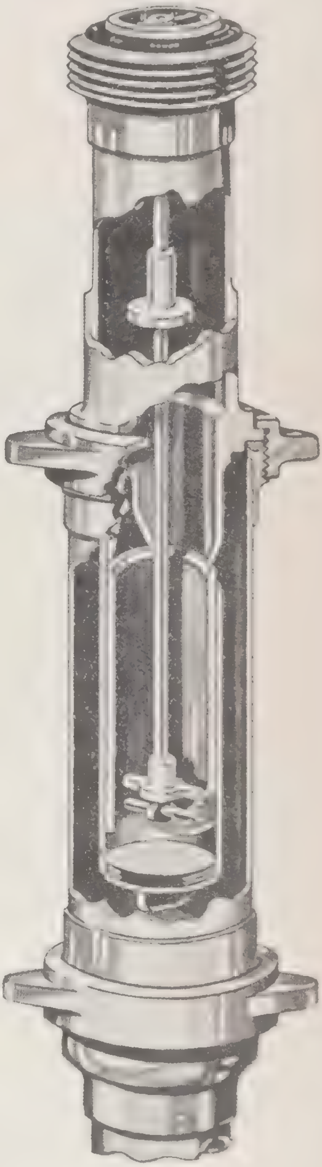
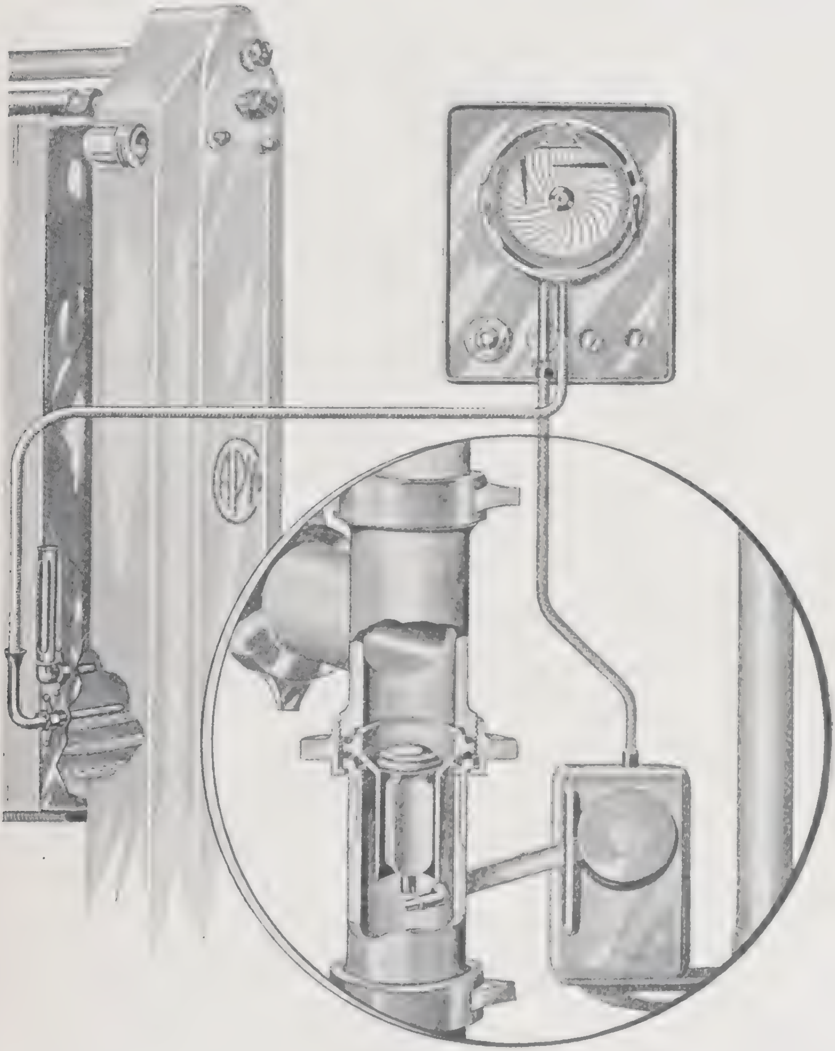


Fig. 42. Flow control valve (section).

By courtesy of the Aluminium Plant and Vessel Co. Ltd.

milk is pumped by a constant speed A.C. synchronous-motor pump from the tipping tank through a flow controller to the regenerative section of the heat-exchanger, where it is preheated to approximately 157° F. to allow of effective filtration. Duplicate filters are usually employed of the type mentioned on pp. 69 and 70. It is important to note that the changeover from one filter to the other must be gradual, and the filter coming into operation must be thoroughly warmed up before



By courtesy of the Aluminium Plant and Vessel Co. Ltd.

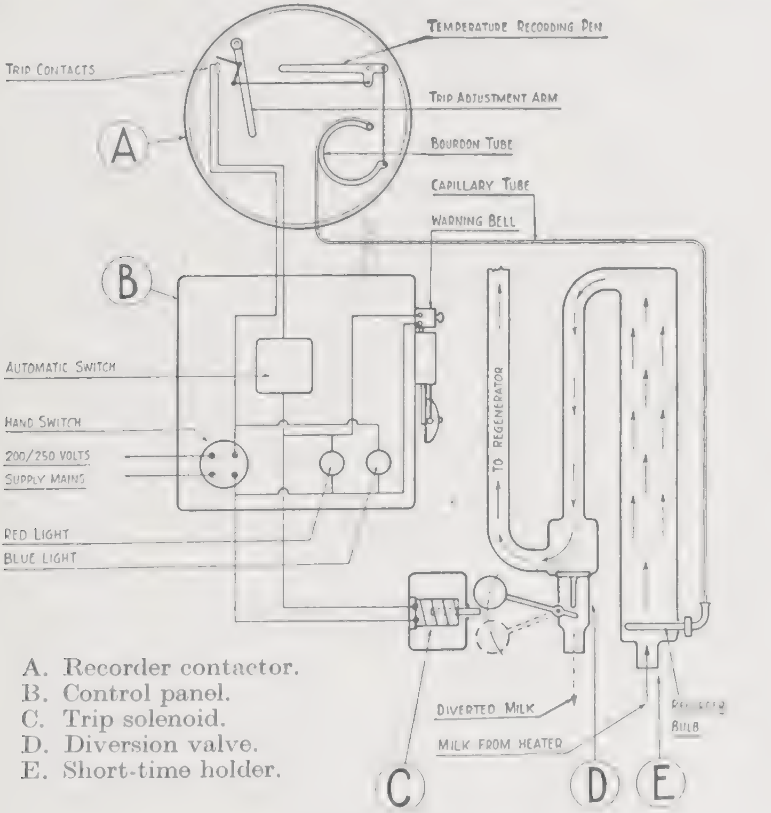
FIG. 43. A.P.V. Flow-diversion valve (enlarged section).

milk is allowed to enter, otherwise the flow-diversion valve will operate. From the filter, the milk returns to the heater where the temperature is raised to approximately 162·5° to 163° F. At this temperature the liquid enters the holding portion of the apparatus at whose inlet is located the bulb of a combined temperature recorder and flow-diversion valve controller, together with an indicating thermometer. The holding section shown in Fig. 41 is fitted with perforated baffle plates, which cause the flow of milk to be retarded so that its passage through this portion of the apparatus takes not less than 15 seconds. At the end of this period, the milk passes through the flow-diversion valve and back through the regenerative, water- and brine-cooling sections, its final temperature being reduced to 40° F.

Two devices which are provided require special mention. The *flow controller*, illustrated in Fig. 42, is designed to give a steady and constant flow of milk to the apparatus and is extremely important, as any variation in flow must adversely affect the efficiency of temperature control. This is a simple, easily-cleaned unit, fitted into the pipe-line. The milk enters at the base, passes through specially-shaped ports into the shell and travels upwards past a control button. When the flow increases, this button operates and reduces the size of the ports, thus restricting the flow to a pre-determined level. The capacity of the unit can be varied according to the size of the button employed.

The other important unit is the *flow-diversion valve* shown in Fig. 43, while the control system is illustrated in Fig. 44. This directs any sub-temperature milk leaving the retarding section back into the raw milk pipe-line in order that it may be returned for further treatment. When the plant is operating normally, a blue light is always visible over the temperature recorder. If the temperature of the milk at the entrance of the holding section falls, the pen arm of the thermograph moves, making a simultaneous electrical contact. This contact operates a solenoid which withdraws a pin and allows a weight to fall and the valve to open, diverting any milk which is below the requisite temperature. As this valve opens, a red light appears and a warning bell informs the operator that the flow has been diverted. An automatic control is provided which prevents the operator re-setting the valve until the temperature has been re-established at the requisite level for at least 30 seconds. Hot water temperature controls are also provided.

The most modern type of *A.P.V. short-time apparatus* incorporates the newly-produced "*Paraflow*" *heat-exchanger*, giving increased milk capacity and easier cleansing. A built-in continuous filter is provided (see Fig. 12) and an improved flow-diversion valve is fitted while all controls and the air-insulated holding section are centrally mounted in a stainless-steel, moisture-proof panel as shown in Fig. 45.

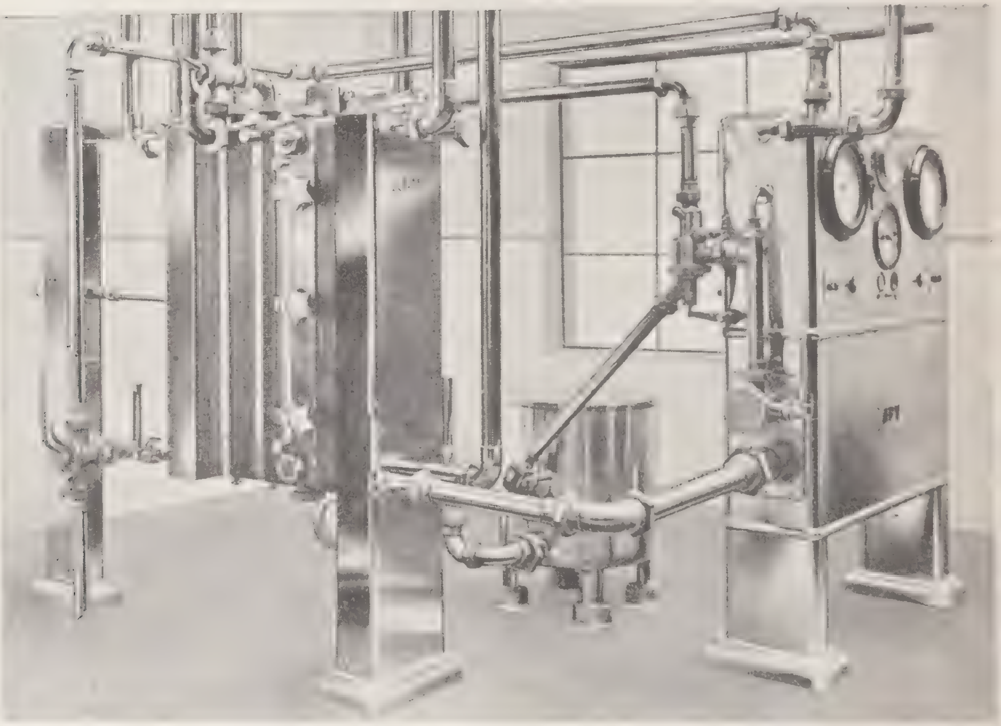


A. Recorder contactor.
B. Control panel.
C. Trip solenoid.
D. Diversion valve.
E. Short-time holder.

By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 44. A.P.V. Short-time pasteurisation control system.

In the *Cherry-Burrell* "*Superplate*" plant, the stainless-steel holding tube, in which the milk is retained at the necessary temperature for 15 seconds, is surrounded with circulating hot water and also insulated with air. In addition to an indicating thermometer, whose bulb is inserted at the final discharge point, a recording instrument is similarly placed. This latter apparatus acts as controller and operates the flow-diversion valve shown in Fig. 47, should the milk temperature fall below the requisite level. It also records the final milk temperature and shows the starting, stopping and working of the milk pump. A typical control panel is illustrated in Fig. 28, p. 114. This apparatus is much similar in appearance to that previously described, but possesses certain modifications. The plates are provided with "knobs" in place of grooves and with bonded gaskets in the heating and cooling sections of the plant, while, as already mentioned, a tube is provided in place of a retarding chamber.

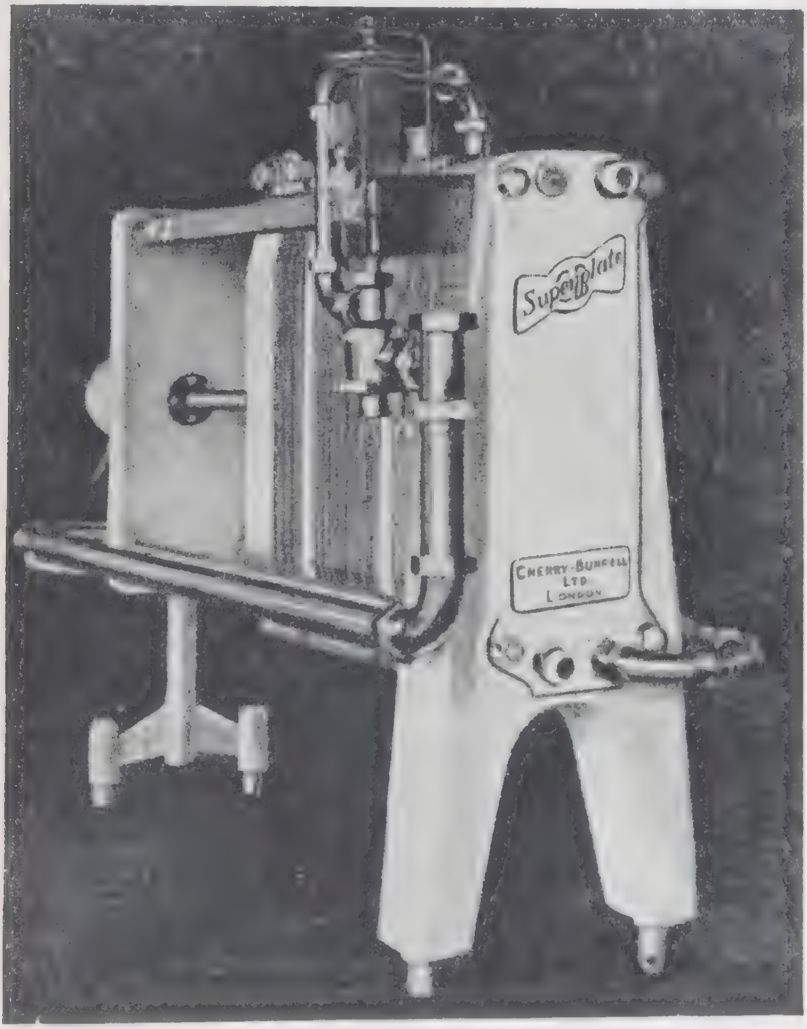


By courtesy of the Aluminium Plant and Vessel Co. Ltd.

FIG. 45. A.P.V. "Paraflow" H.T.S.T. pasteuriser showing control panel.

Another interesting apparatus is the *Graham-Enock "Gem" Short-time Pasteuriser*, illustrated in Fig. 48. This is an extremely novel and compact unit of unique design in which milk is processed in a film approximately one-hundredth of an inch in thickness as it flows over ingenious weir troughs. The raw milk enters the regenerative section and flows upwards *viâ* a twin filter unit to the final heating section over which it is distributed by gravity.

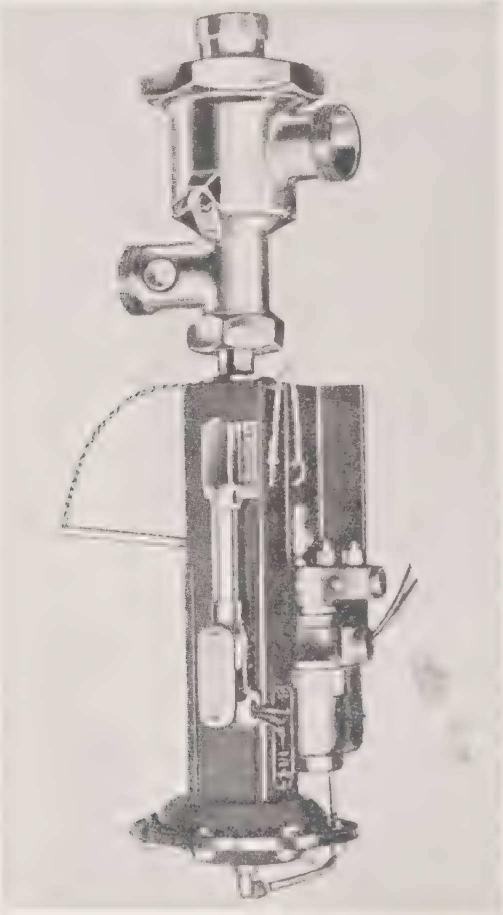
Hot water circulates through the tubes of this final heater and the surfaces of these tubes and the velocity of the water passing through them is arranged so that the water temperature is only 1° F. above the required milk temperature. On leaving the heater, the liquid is caught in special V-shaped troughs. These really consist of two troughs, one inside the other, with a space of one-eighth of an inch between, the edges of the outer trough being below those of the inner one. The base of the inner trough possesses openings of a suitable size and the milk cannot overflow



By courtesy of Cherry-Burrell Ltd.

Fig. 46. Cherry-Burrell short-time "Superplate" pasteurising apparatus showing holder tube.

as the heated liquid passes out through the openings provided at the base. The milk passes through the space between the two troughs in an upwards direction and flows over the edges of the outer one. A constant level is maintained in the inner trough,

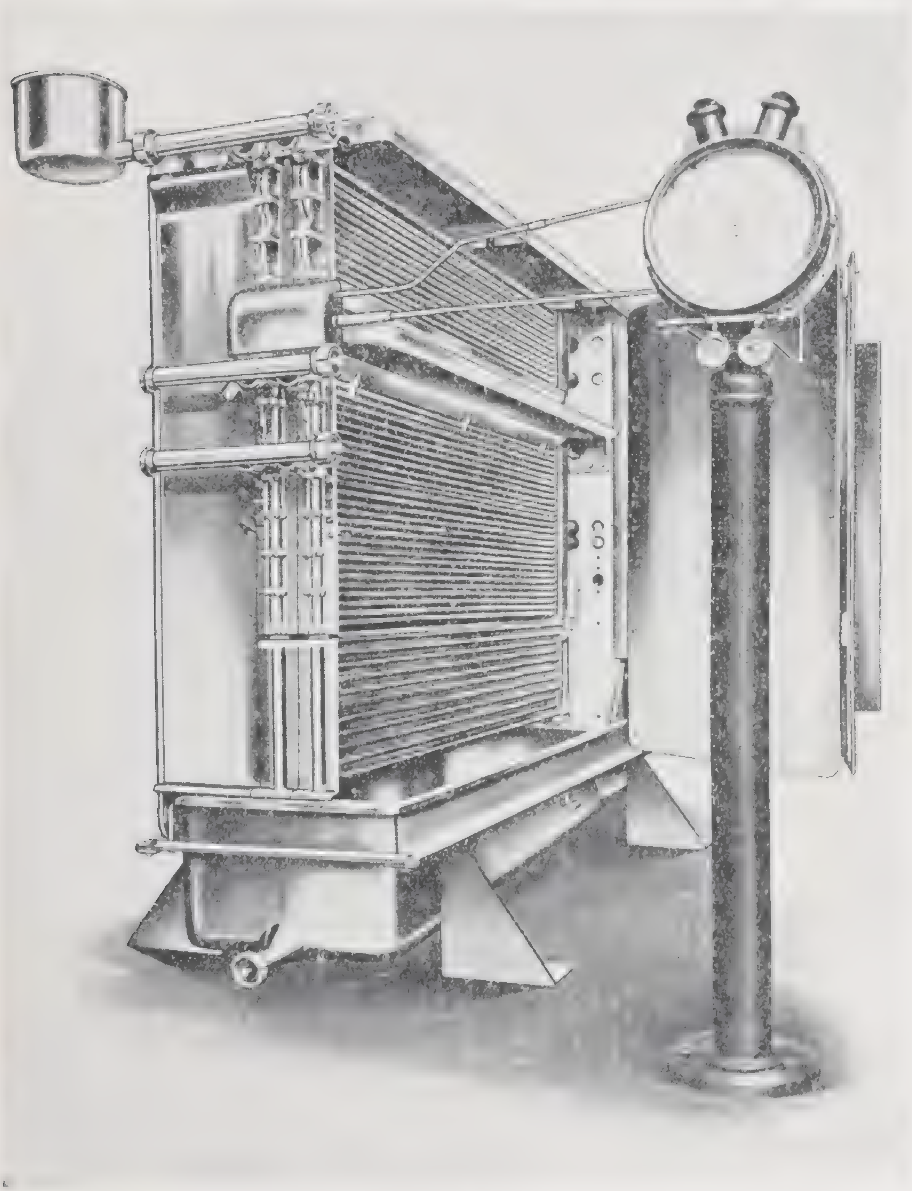


By courtesy of Cherry-Burrell Ltd.

FIG. 47. Cherry-Burrell flow-diversion valve.

the liquid being maintained at the requisite temperature for 15 seconds plus an adequate margin. As the inner trough is emptied from below and filled from above, there is no chance of any milk failing to receive adequate treatment.

After leaving the troughs, the milk is collected in a distributing tank, from which it flows to the flow-diversion valve. The valve is electro-pneumatically operated by a bulb placed in the outlet pipe of the final heating section. When the plant is working normally, a green light is always visible on the temperature-recording panel, but, should the milk temperature fall, a red warning light appears, an alarm bell rings, the flow-diversion valve operates and all sub-temperature milk is discharged from the plant. If working normally, the liquid passes through the flow-

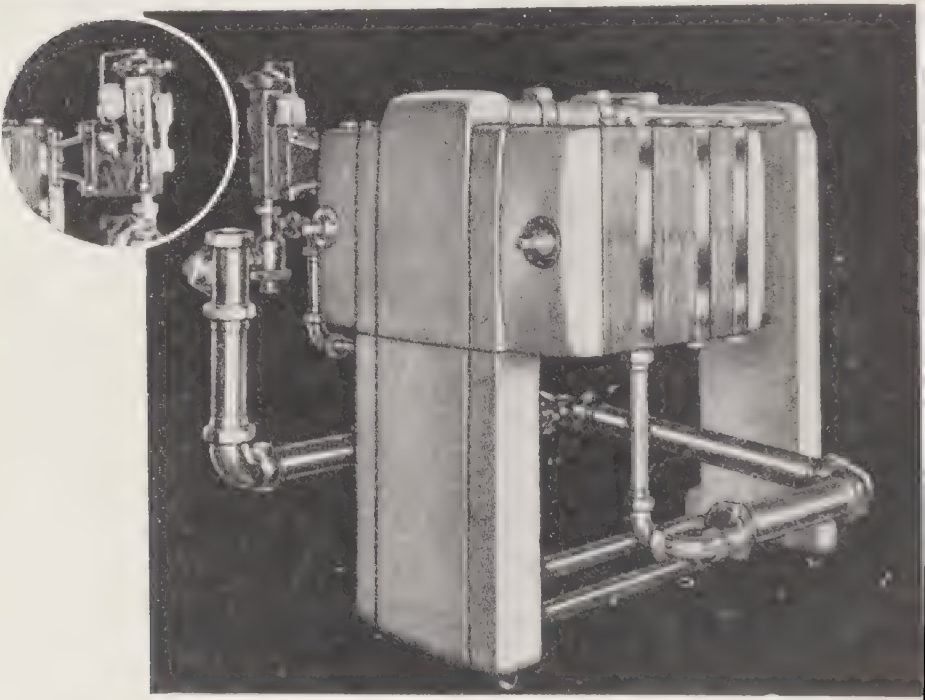


By courtesy of the Graham-Enock Mfg. Co. Ltd.

Fig. 48. "GEM" Short-time pasteurising apparatus.

diversion valve to a distributor tray above the regenerato Here its temperature is reduced to 95° F. and it is furthe cooled by mains water to within a few degrees of the coolin medium. Final cooling by refrigeration is provided, after whic the milk falls into a balance tank immediately below th apparatus.

Temperature control is provided by means of a bulb placed i the hot milk outlet, operating through a standard recorde

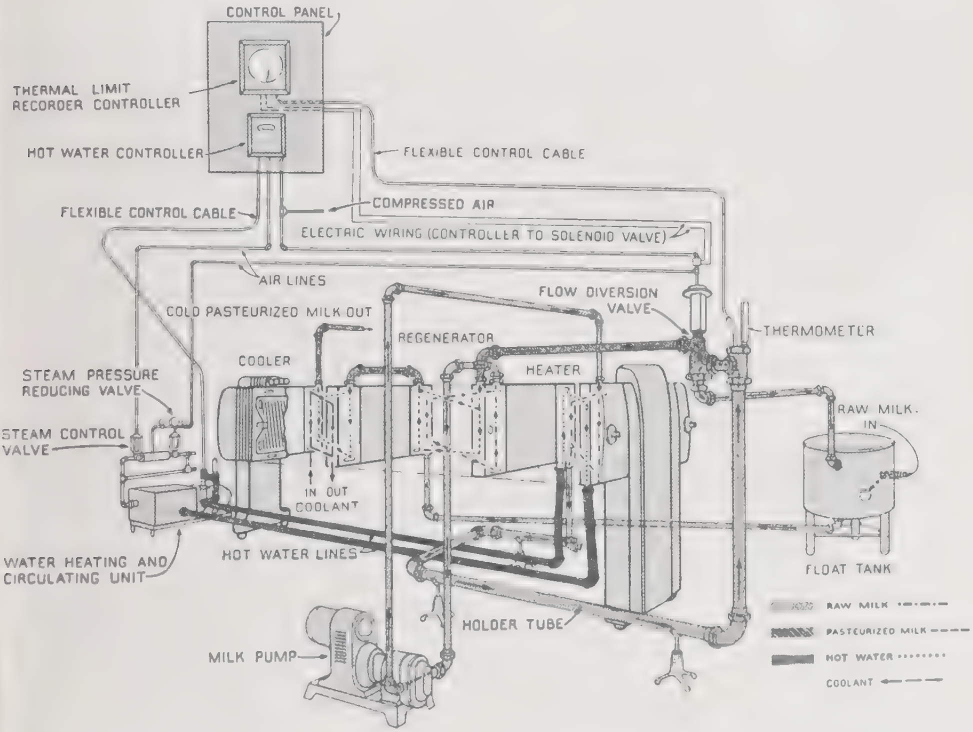


By courtesy of the Creamery Package Co. Ltd.

Fig. 49. C.P. "Full-flo" Short-time pasteuriser (showing holder tube and (ins flow-diversion valve).

controller to a steam diaphragm which causes variation in t temperature of the hot water circulation. A second instrume controls and indicates the temperature of the hot water and th is placed in the hot water line, allowing the injection of furth steam when required. This dual adjustment of temperatur gives extreme sensitivity and satisfactory temperature control achieved. The machine is totally enclosed, is simply opened up a easy to clean, the breaking of pipe-line joints being unnecessary.

The *C.P. "Full-flo" High-temperature Apparatus*, illustrat in Fig. 49 is another plant of outstanding merit in which a tube holder is employed. The one-piece stainless-steel plates of the regenerative and cooling sections are much similar to the types illustrated previously and as the milk crosses the plate, the cycle of diverging flow to variable flow to undulating flow is repeated over and over again. Velocity of the liquid not only varies constantly but it turns over and over on its passage through the apparatus so that fresh portions are constantly in contact with the plates. Large quantities of milk may be efficiently handled, fully automatic and suitable temperature controls being provided. A flow diagram is illustrated in Fig. 50, while Fig. 51 shows the lay-out of the plant.

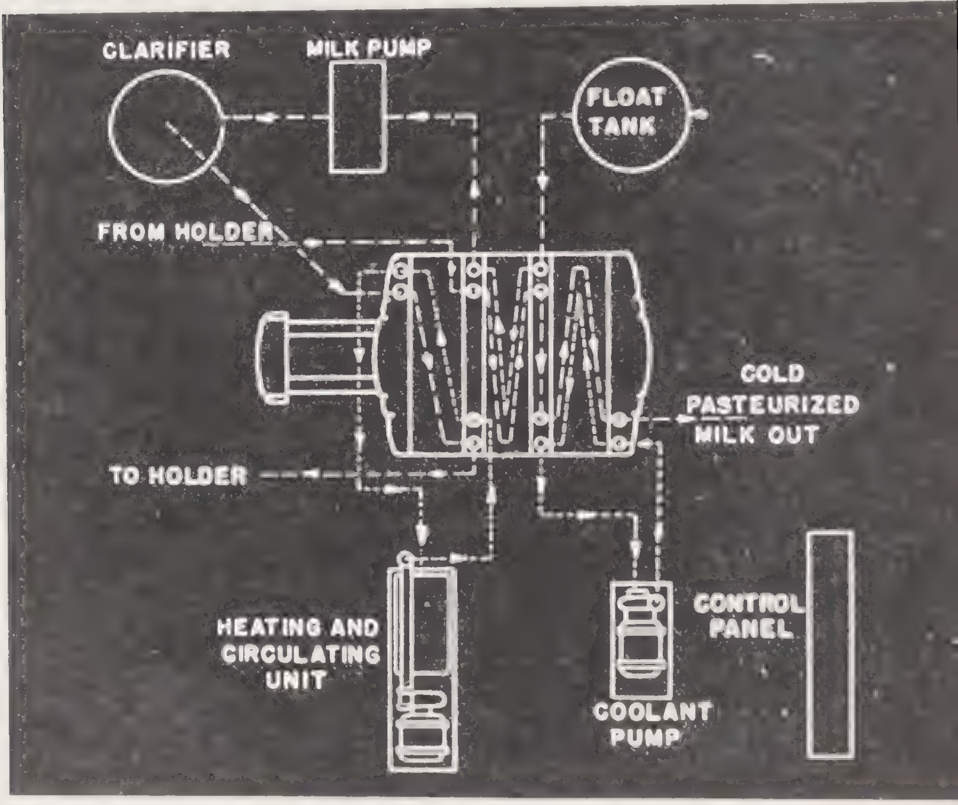


By courtesy of the Creamery Package Co. Ltd.

Fig. 50. C.P. High-temperature, short-time pasteuriser (flow diagram).

A further example of short-time apparatus is the "*Electro-Pure*," which employs electricity for treating milk. This type of plant has not yet been employed in this country, although it was first tried out following experiments by Beattie and Lewis at Liverpool University in 1911. It was in commercial use in the United States of America before the first short-time plant was experimented with in these islands and receives more extended mention on pp. 165 and 166.

With all short-time pasteurisers, certain disadvantages may arise according to the type of apparatus employed. Plate apparatus requires special care as regards the gasket which is



By courtesy of the Creamery Package Co. Lt

FIG. 51. C.P. Short-time pasteuriser (lay-out plan).

fitted round each plate. As these gaskets become worn or defective, they must be replaced immediately, while special care i also needed in cleansing. When brine is used for final coolin some loss of cooling agent is likely to result when the plates ar opened for cleansing purposes, while complete drainage of mil from the system is not possible at the termination of processin With double-tube apparatus, the temperature control system i generally somewhat slower in response than is the case wit the plate type, while with both plants, refrigeration costs will be higher than when low-temperature methods are employed.

There is no doubt that this system will make a special appeal to operators wishing to process their milk in an economical fashion and, now that the Minister of Health has officially recognised this method, it may be safely applied to all dairies, irrespective of size. The small safety margin provided is sufficient to guarantee satisfactory results, provided care is exercised, but the automatic controls which are fitted must be maintained in perfect working order and be completely reliable to ensure adequate safety. There is nothing to prevent any distributor installing this type of apparatus even if there is no desire to retail milk as a designated article. When compulsory pasteurisation is introduced, plant of this type will be accepted as complying with the legal requirements dealing with the matter. It should be noted that the plate or tubular types can be readily converted into normal heat-exchangers for use with low-temperature plant if desired.

The process has been recognised for some time by various Public Health Departments in the United States of America as a suitable method of pasteurisation, but such recognition has been accompanied by the proviso that all milk so treated must be heated to a temperature of 160° F. for not less than 15 seconds in order to secure an adequate safety margin. It will be seen that the safety margin in this country is rather greater than this.

Suitable and satisfactory control devices are essential for safety and in order that heating and holding may be regulated within specified limits. Such apparatus must therefore be extremely sensitive and give a speedy response to any changes in temperature. It is necessary to emphasise again that the safety margin provided lies within extremely narrow limits of time and temperature. A constant water temperature is a prime essential for heating milk to the required pasteurising level, therefore a steam control valve, set to maintain constant pressure of steam for heating purposes, must be fitted. This valve governs the temperature of the incoming hot water and by this means the final temperature of the milk is maintained. The control is operated by the heating water and, if the water temperature remains steady, the outgoing liquid will leave the apparatus at a constant temperature.

A milk temperature controller must also be regarded as a vital fitment. This instrument should be fixed preferably at the inlet of the retarding portion of the apparatus, and if the temperature of the treated milk falls, this controller will operate the flow-diversion valve which automatically diverts milk for re-treatment. Any fall in temperature and frequency of such diversions must be recorded on the chart for future comparison. In order to ensure that milk leaves the apparatus at a sufficiently high temperature, it would be advisable to fit a recording thermometer and an indicating instrument at the outlet of the holding section. This practice is not always carried out in this country, milk temperature being controlled from the temperature of the ingoing milk as it leaves the final heating stage. The siting of the recorder bulb at this point is of considerable importance. With apparatus of this type, there is a certain time lag and several seconds may elapse before the mechanism will operate Should the milk temperature fall, such liquid could be well on its way through the holding section before diversion could take place and a quantity of under-heated milk could be passed through the final stages of processing. In American practice, the temperature of the milk as it leaves the holding section operates the flow-diversion valve. Practically, it will be found that the time lag of the controller bulb placed at this point must be extremely short, although with supersensitive instruments there is little doubt that the operation of the flow-diversion valve from this point would be sound. When the flow has been diverted on account of a fall in temperature, the valve should be provided with a device which renders the forward flow of milk impossible until at least 30 seconds have elapsed following a return to normal temperature levels. A thermometer and a temperature recorder should also be fitted at the outlet for the brine-cooled milk.

The recorder at the inlet to the retarding section is of consider-able importance. The pointer requires to be set to the required diversion temperature and should be maintained in correct adjustment. A close watch must be kept upon the relationship between the temperature recorded by the pen and that shown by the indicating thermometer which is also fixed at the retarder inlet. It is essential that an additional pen should be fitted to show the extent of any diversion of the flow of milk.

It is important that thermometers recording the temperature of the hot water employed in heating milk should be frequently examined. While provision is usually made for flow diversion when the temperature of milk falls below 162° F., any increase in such temperature as may occur is liable to be overlooked. Such fluctuations will damage the final product, cause the milk to become cooked on the plates or inner surfaces of the apparatus and result in inefficient heat-exchange, necessitating increased labour for cleansing and sterilisation.

The introduction during the War of the high-temperature short-time process has brought about radical changes in milk treatment, together with differences of opinion as to its efficacy. In spite of this, many distributors would no doubt welcome the opportunity of being able to treat milk in this manner if the process could be carried out with liquid already in bottles. Mr. A. G. Enock, the originator in this country of the modern in-bottle process, has undertaken prolonged investigation into the feasibility of adapting this method of treatment to milk in bottles and, following extended trials, has produced preliminary designs for commercial installations which will no doubt soon be available when conditions become more settled. The high temperatures (162° to 163° F.) of the hot bottles when filled, renders crating by human hands impracticable and an automatic apparatus has been designed which picks up the containers from the crates and conveys them, after processing, through a cooling bath which, by means of mains water, reduces their temperatures, so that they may be re-crated by hand before final cooling takes place. It is hoped that plants for treating milk by this method may eventually be available for processing between 300 and 30,000 gallons per day.

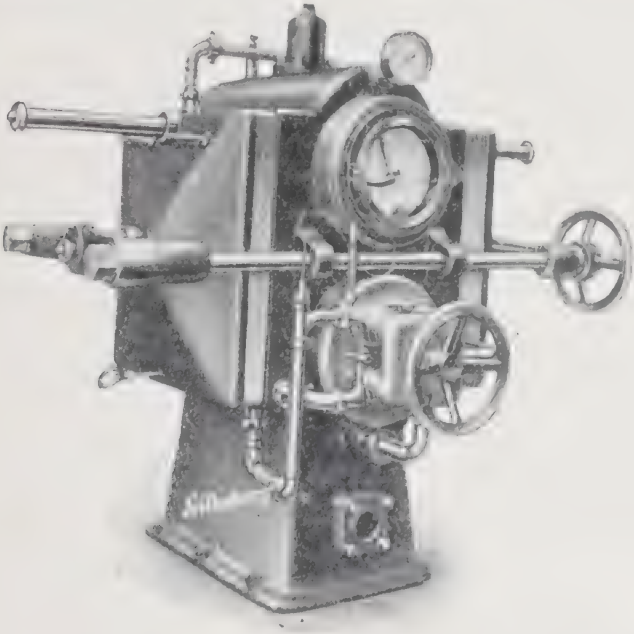
(2) **Stassanisation.** This is a comparatively new short-time method of processing and takes its name from its inventor, Dr. Stassano, an Italian member of the Pasteur Institute in Paris. Stassanisation is actually a modification of the "Flash" method of pasteurisation and is somewhat different from the accepted short-time method. Up to the present it has not been recognised as complying with the statutory requirements dealing with this method of processing. Its first extended trials were carried out at the Danish State Experimental Farm, but Dr. Stassano has made tests with the milk supply of Strasbourg and elsewhere. Two types of apparatus have been devised for the purpose, one,

the older type, being much more cumbersome than the later model.

Milk is processed in a completely-closed tube, being distributed in thin layers without access to air, each layer being about one-twenty-fifth of an inch in thickness. The liquid is heated rapidly under slight pressure, in such a way that it is unable to lose its carbonic-acid content. The temperature attained is approximately 165° F., the milk being in contact with the heating surface for approximately seven seconds in the latest model. Rapid heating is followed by speedy cooling to a temperature of 58° F. The heating agent is water at a temperature of 166·8° F., which is slightly above stassanising temperature.

The older type of plant consisted of a closed, pressureless filter through which milk flowed by gravitation, a slow-working pump which exerted no mechanical influence upon the liquid, a heat-exchanger and cooler, through which the milk was led in a regular spiral course without acute angles, and a stassaniser. This latter apparatus consisted of three drums, each possessing four double tubes. A space of 1 to 1·25 millimetres was provided between the inner and outer tubes through which the milk flowed. The total length of tubing was approximately 22 yards, being fairly equally distributed between regenerator, stassaniser and cooler. The tubes were continuous and connected in pairs, each set being joined by means of end-pieces in the drums. The connection between the individual tubes was established through fixed covers, which were tightened by means of hand-operated wheels. The joints were milk- and water-tight, and any leakage, which could only be due to insufficient tightening of the end-piece, was quickly detectable. The water temperature was maintained by the admission of steam, while the milk was circulated by means of the pump provided, another pump being fitted for the circulation of hot water. Thermometers were provided at the inlet and outlet of each drum, so that adequate temperature control was maintained, while recording instruments could be fitted if desired. The pump could be adjusted to vary the milk pressure as required and was designed to ensure that air was never pumped into the liquid.

The milk was filtered, either flowing from the filter by gravity or being pumped by specially-designed pumps, to the regenerator, where it met the hot liquid from the stassaniser. Heat was exchanged between hot and cold milk, the heated milk leaving the regenerator at 122° F. It was then pumped through the stassaniser, being further heated to 165° F. and maintained at this temperature during its progress, after which it returned to the regenerator to yield a portion of its heat to the incoming cold milk. The temperature of the hot milk was reduced to 86° F. by this means. The liquid finally passed to the cooling section where the desired temperature was achieved by means of water or other cooling agent. The time taken to pass through the plant from the receiving tank to the outlet was approximately 2½ minutes. This type of plant could handle from 66 to 1,760 gallons of milk per hour according to size.



By courtesy of Hiron and Rempler Ltd.

FIG. 52. "Silkeborg" Stassaniser.

The modern plant shown in Fig. 52 is much more compact, the principles involved in treatment being similar to those described above. This is a combined apparatus consisting of stassaniser, plate heat-exchanger and cooler, the plate sections serving as storage for hot circulating water. One or more stassanising drums can be provided within a common framework, each drum having a capacity of 440 gallons of milk per hour. The cleansing of the tubes, which are constructed of stainless steel, is simplified, each tube being just over 1 yard long. Quite lengthy tubes were provided in the original apparatus, as already mentioned, but experiments have shown that the provision of shorter components in no way affects the quality or safety of the final product.

It is claimed that cleansing operations are quickly accomplished, but an obvious disadvantage is the labour necessary for dismantling. Such operations are usually commenced by pumping clean cold water through the plant until this water on emerging from the cooling section is free from any trace of milk. A weak soda solution or other detergent is then circulated repeatedly through the tubes, followed by very hot water. Steam is finally blown through for sterilisation purposes. When the end-pieces are opened, the inner tubes can be extracted and cleansed by means of the special brush provided.

The plant is more economical in the use of steam than is the normal low-temperature apparatus and, from a distributor's point of view, additional economic advantages are minimum working expenses, no losses through evaporation or any spoiled returns, that is, milk of decreased value. From a public health standpoint, the results of experiments carried out at the Danish State Experimental Farm and by other bodies must be mentioned. No difference could be detected in odour, flavour, or appearance of milk before or after treatment, while a satisfactory creamline was exhibited. The liquid kept fresh for 48 hours and at the end of that period did not possess any disagreeable taste. The process did not influence the ability of the milk to curdle following the addition of rennet to any great extent, the digestibility of the proteins was retained, while vitamins A, B and C were not influenced by processing. It was found that only 8 per cent. of the soluble protein was altered during treatment and the majority of non-pathogens were destroyed, as were all coliform organisms, together with any pathogenic bacteria present in the raw milk prior to treatment. The process was found to be economical in the use of steam, power, water and brine and very little slime or milk-stone accumulated in the tubes. As with all other methods of milk processing, strict temperature controls are essential.

The first stassanising plant to operate in this country was constructed in Stockport and the method has given complete satisfaction in everyday use. One experimental plant has been installed in a London dairy while a few others exist in various parts of the country. In view of the small number of experiments carried out by responsible authorities, the plant should be considered with an open mind until sufficient evidence is available to enable a decision to be made as to whether this method of treatment is likely to yield results approximating to those obtained by the present low-temperature method. Given adequate, efficient temperature controls and fitted with a suitable flow-diversion valve, it would appear, however, that this type of plant might be rendered suitable for the high-temperature processing of milk in accordance with the present legal requirements.

(3) **The "Electro-Pure" Process.** This short-time method, which employs electricity as the heating agent, is fairly popular in America. The temperature of the milk is raised by means of an electric current passing between carbon electrodes in a small, specially-constructed chamber. This chamber, which has a cross-section of approximately 2 inches, possesses two walls consisting of flat, carbon electrodes separated by intervening walls of plate glass. The current passes through the milk as it flows upwards between the electrodes, the electrical resistance of the liquid resulting in liberation of heat, while the extent of heating is regulated by the amount of current supplied. Cold milk flows from a storage tank into a balance tank in which the level of the milk is controlled by means of a float. It is then pumped through a heat-exchanger where the temperature is raised to 120° F. by means of the outgoing milk. This preheated milk then travels through the electrical heating chamber, its final temperature being governed by an automatic device. After treatment the milk passes through a flow-diversion valve and any liquid which has not attained the desired temperature of 160° F., this being the temperature employed in processing, is redirected into the balancing tank for further circulation through the apparatus. If the temperature is correct, the milk passes through the heat-exchanger, where it is cooled and finally flows to the bottling machine. This is another instance where, provided adjustments are made as regards time and temperature, the apparatus would appear to be suitable for the treatment of milk by the short-time process, in order to conform with the regulations now in force. Holmquist has reported on tests carried out by him on

milk treated by this method and he has stated that a temperature of 153·9 F maintained for 12·4 seconds rendered tubercle-infected milk non-pathogenic to guinea-pigs.

Two other types of apparatus employing the modernised "Flash" method of operation are water-heated and tubular in type. These are known as the "*Isotherm*" and the "*Precision*" methods, while another type, known as the "*York Plate*" apparatus, is a machine of the multiple-plate type very similar in design to the modern plate heat-exchanger.

CHAPTER IX

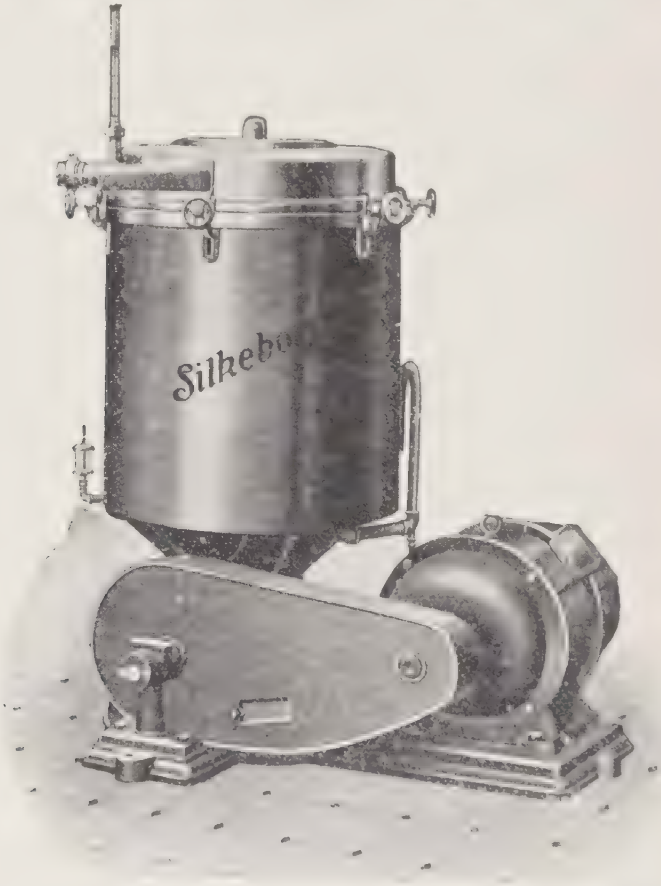
OTHER PROCESSING METHODS

In view of Defence Regulation 55 G, no volume dealing with the pasteurisation of milk can be considered complete unless some mention is made of the other methods of milk treatment which are more or less in general use and rely on some form of heating for their efficiency. The processes of the greatest importance are probably "Flash" pasteurisation and the "Continuous-flow" method, but sterilisation, homogenisation and irradiation require to be considered. It is also necessary to mention a new method of vacuum pasteurisation.

(1) "Flash" Pasteurisation. This was the original method of milk treatment, the liquid being heated to temperatures of approximately 140° to 176° F. or even higher and then immediately cooled. It was found to be quite suitable for those dairymen whose main object was to improve the keeping qualities of their milk, but it was never accepted by public health authorities and has fallen into disrepute, now surviving only in butter and cheese manufacture. Fresca's pasteuriser, first manufactured in 1881, was the forerunner of this type of apparatus, and the first Danish pasteuriser was copied by Professor Fjord between 1886 to 1890 from Fresca's design. "Flash" pasteurisation bears a strong resemblance to the "Continuous-flow" method which is considered later in this chapter, except that milk is not retained for any period during its passage through the plant. In the usual type of apparatus, the liquid enters a hollow, vertical cylinder at the base, and, by means of a rotating device, is distributed by centrifugal force in a thin film over the inner surface of the cylinder, finally leaving at the upper end. This cylinder is surrounded either by a steam- or a water-jacket or a combination of the two.

The apparatus employed for "Flash" pasteurisation in this country is almost entirely of Continental manufacture, very few plants of this type being produced in Great Britain. This is probably due to the fact that, on account of the impossibility of controlling time and temperature, this method has not been recognised by the Minister of Health as a means of providing efficient pasteurisation. It is extremely doubtful if this apparatus could be employed even for short-time processing on account of its many disadvantages.

In view of the quantity of milk which can be handled by these plants, they appear extremely small when compared with other types of pasteurisers. They are comparatively inexpensive to install but require a large amount of steam for effective working as, owing to their relatively small heating surface, it is necessary to raise the temperature of the heating medium to a much higher level than the final temperature to which the milk requires to be finally heated. Such excessive heating often causes portions of the liquid to become overheated, with consequent alteration in its chemical character. Some form of pump, driven either by means of steam or electricity, is necessary to



By courtesy of Hiron and Rempler, Ltd.

FIG. 53. "Silkeborg" direct-drive pasteuriser.

pass milk in a continuous stream through the apparatus and the action of pumping alters the texture and affects the cream-line. In addition, foaming, which is a condition to be avoided in any pasteurising plant, is extremely prevalent. The apparatus is illustrated in Fig. 53.

"Flash" pasteurisers possess many serious disadvantages; this is particularly so with the older type of apparatus. A uniform temperature is difficult to maintain, while variations in milk flow cause fluctuations in the final temperature of the liquid. During treatment, a "cooked" flavour is often acquired. The nutritive value of the milk is seriously impaired owing to the chemical and physical changes which occur on account of excessive heating, and owing to contact with air. In many instances, owing to the rapid passage of milk through the apparatus, the liquid is not always in contact with the heating surface long enough to be efficiently processed. Indeed, some milk may not even reach the requisite temperature.

There is no doubt that "Flash" pasteurisation does, if correctly carried out and supervised in an efficient manner, reduce the bacterial content of milk and, to that extent, the keeping quality is improved. The commercial advantage of such improvement is seriously offset on account of the alterations which take place in milk and the effect excessive heating has upon the cream-line. No reliance can be placed upon the total destruction of pathogenic organisms which milk may contain owing to the possibility of variations in temperature, such variations allowing the bacteria to escape destruction. It is impossible, therefore, to obtain the results which should always follow efficient pasteurisation. Legislation is required to prevent the sale of milk treated in this manner as the method cannot guarantee a "safe" milk in every instance. "Flash" pasteurisers are sometimes used for preheating milk when the low-temperature method is employed, although in such cases they work at greatly reduced temperatures.

Two modifications of this method are now in use in many parts of the country, although a different apparatus is employed to that already described. These systems are the Short-time process and Stassanisation; both of these have been considered in the previous chapter. These methods possess the advantage of efficiency with economy without any of the disadvantages of the "Flash" process. A system of *High-temperature pasteurisa-*

tion, during which milk is heated for a few seconds at temperatures between 176° and 185° F., is employed in the Scand navian countries, and, while temperature controls are provide considerable variations in heating ensue.

(2) "CONTINUOUS-FLOW" PASTEURISATION. Although thi process is termed "continuous-flow," it should not be confuse with the "Flash" method of treatment. The underlyin principle is that milk is pumped at a regulated speed, whic is arranged so that the liquid is retained at temperatures betwee 145° to 150° F. for 30 minutes during its progress through th apparatus. The milk is preheated before treatment takes plac and the amount of liquid passing through is supposed to b sufficient to prevent a temperature drop of more than two o three degrees Fahrenheit. The apparatus is generally surrounde with a hot-water jacket to maintain the milk temperature an consists of a series of long tubes which are arranged in row The flow, although continuous, is retarded to some extent as th milk has to pass through a series of baffle plates before leavin the apparatus. In order to ensure that the liquid is in contac with the heating surface for the requisite period, the volum of milk passed through is equal to the capacity of th apparatus.

This method of treatment possesses many commercial advantages. The apparatus is usually of simple design, affording eas working and cleansing, while the milk temperature may be controlled within fairly close limits during treatment. The operat is able, therefore, to produce an article which has suffered litt appreciable change during processing; in spite of this th apparatus cannot be considered highly efficient. Hamill ha drawn attention to the comparative efficiency of this meth and, following investigations, has stated that a plant which show an efficiency of 50 per cent. under normal working conditions, ca be classed as highly satisfactory. He points out that the efficien of such a plant at a given rate of flow can be defined as the rat of the shortest time during which any particle of milk pass through, to the time during which a quantity of milk equ to the contents of the apparatus flows through, the whole bein expressed as a percentage.

This process will reduce considerably the bacterial content any milk treated, the great disadvantage being that comple destruction of pathogenic bacteria cannot be guaranteed. Many "continuous-flow" pasteurisers are employed which allow some portion of the liquid to pass through in less than the requisite time. Faulty design is usually the cause of this defect, but convection currents, swirls, and variations in velocity also permit some milk to escape adequate heating. Any process must retain milk for the full period at the required temperature if it is to be 100 per cent. efficient and, with this method, such efficiency cannot be obtained in practice.

The absence of any guarantee that all pathogenic organisms are destroyed prevents this method of treatment being satisfactory from a public health standpoint. Commercially, certain advantages are obtainable as, with the reduction in the liquid's bacterial content, the keeping quality is considerably improved. It cannot be too often emphasised, however, that no method can be recommended which does not destroy all the more common types of pathogenic organisms likely to be present in raw milk, while the slight reduction in temperature which occurs as milk moves through the apparatus, is not in accordance with the principles of efficient pasteurisation.

(3) STERILISATION. Confusion still appears to exist regarding the difference between sterilised and pasteurised milk. It is therefore necessary to emphasise that the word "sterilised" is employed to denote milk which has been heated to temperatures of 212° F. and above, in bottles which are vacuum sealed, and which should remain fit for human consumption for at least seven days. The objects of the process are to destroy all pathogenic organisms likely to be present and to produce an article which possesses lengthy keeping qualities. Heating milk to the high temperatures attained in this process has a detrimental effect upon the final nutritive value while the resultant product possesses a distinct flavour which, however, appears to be enjoyed by many consumers.

A dairyman named Anthony Hailwood was the first person to apply the method of sterilisation to milk, in the year 1894. He filtered and bottled the liquid in swing-stoppered bottles, the stoppers being left loose when the bottles and their contents were placed in closed circular vats. A container of water was placed in the centre of each vat and a tall thermometer was inserted in this. The milk was brought to boiling point by steaming for

20 minutes, a similar period being allowed for sterilisation with the steam shut off. When treatment was completed, each vat was opened and the stoppers of the bottles closed down. To prevent formation of cream plug in the necks of the containers, they were placed upon their sides in racks during which time they cooled to atmospheric temperature. The process was adopted by the Liverpool Corporation but later discontinued as it was reported that infants fed on sterilised milk tended to develop rickets. The further development of this method was then continued in London and the Midlands.

In 1905, Nielsen, a Dane, introduced a process which he termed "Flash Sterilisation," the apparatus being of the continuous-flow type. Milk was passed through a long tube, which was surrounded by a jacket containing steam under pressure. A temperature of 265° to 275° F. was reached, being maintained for 40 to 45 seconds, and this was said to be sufficient to destroy all bacterial spores while the short heating period caused little caramelisation. This plant made no provision for bottling immediately after treatment and for this reason was not very popular owing to danger of re-contamination, while, in addition, the inventor wished to impose conditions unacceptable to the dairy trade. The plant employed in the early days of this process was almost univerally of Continental origin while even the bottles were imported, being of the swing-stopper type with a capacity of 18½ ounces.

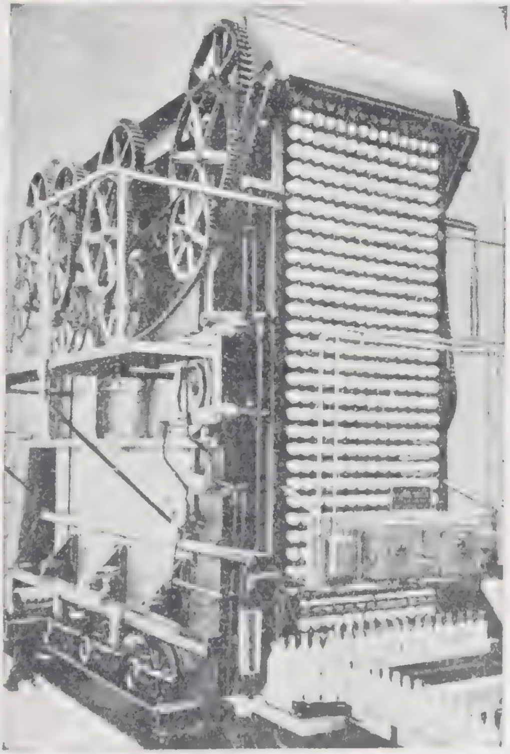
Sterilised milk, the first to be delivered in bottles in this country, is now being sold in large and increasing quantities, particularly in urban areas. It is commonly retailed from general stores, usually situated in poorer localities, and, as a result, the sales of pasteurised milk in those districts have somewhat decreased. On account of its keeping qualities and the even distribution of its cream which is due to homogenisation prior to processing, this milk appeals to many housewives, puddings and other cooked milk dishes being considerably improved by its use. The consuming public are lamentably ignorant of the biological properties of milk and do not realise that immunity from souring and freedom from pathogenic organisms, which are the chief properties of sterilised milk, have only been gained at the expense of loss of food value and that this loss of nutritional properties normally present is by no means unimportant. The bone- and tissue-building salts are rendered less easy of assimilation, the vitamins are either destroyed or very seriously impaired, and the lactic acid organisms are eliminated entirely. In spite of this deterioration in quality, the desires of consumers have forced the large distributors to produce this type of milk to meet an increasing demand. It must be remembered that in spite of its nutritive losses, it is a " safe " milk from the public health viewpoint.

The raw milk is first heated to temperatures between 110° to 120° F., after which it is filtered or clarified to remove dirt and pus cells, is preheated to render it less viscous and to assist its passage through the homogeniser. Heating may be carried out either in a steam-heated " Flash " pasteuriser or in a heat-exchanger, using hot water as the heating agent, the latter method being preferable. The cleaning process is best carried out by a milk clarifier which removes cells and their debris and particles of milk solids which filtration will not deal with. This prevents the deposition of a fine sediment which is brown in colour in the finished product. The homogenisation process, a description of which is to be found on pp. 176 to 180, is carried out at pressures between 2,000 and 2,500 lbs. per square inch, the temperature being in the region of 150° and 160° F., heating again being carried out in the manner mentioned above. This treatment breaks up the fat globules and, if the milk were not subjected to the process, its cream would rise to the surface after sterilisation as a yellow, oily fat, forming what is known as a "cream-plug." The formation of cream-plug was a major difficulty experienced until homogenisation was adopted. After its passage through the homogeniser the hot milk is filled into sterilised hot bottles of a special narrow-necked type, which are either fitted with swing stoppers or sealed with crown corks. The advent of crown corks has enabled conveyors to be used with the elimination of much handling. The actual sterilisation process then commences.

As sterilised milk, although classed as "heat-treated," is not officially graded, no standard method of processing can be demanded and various methods are employed. The first continuous steriliser was introduced into this country from the United States of America, being erected in Birmingham. This apparatus possessed four compartments and the bottled milk passing through was raised to temperatures between 220° and

225° F., at which level it was held for 30 minutes. In the original type of plant, the bottles were immersed up to their necks in water contained in steam-jacketed tanks. The heating agent was maintained at a temperature of 212° F., the bottles remaining submerged in the heating medium for one hour, after which they were cooled by the admission of water to the tanks. This method of processing gave some remarkable results as regards keeping quality, but later it was found that higher temperatures were more satisfactory. In a later type of apparatus, the bottles of milk were stoppered after the milk had expanded and were then subjected to steam pressure until a temperature of 222° to 226° F. was attained. When processing had been completed, they were removed from the heating agent, gradually cooled and crated for delivery. Another method requires that the bottles be placed in a steam chest similar to a horizontal boiler, roughly 10 feet in diameter, with the stoppers loose. Extremely high temperatures can be used if desired with apparatus of this type. A thermometer is fitted which enables the temperature of one bottle to be checked from outside the apparatus. Steam is admitted and the milk is heated to between 220° and 230° F., this temperature being maintained for 25 minutes. Steam is then shut off, the bottles being stoppered while the chest is still hot, after which they are cooled. With this apparatus, a skin is formed on the surface of the milk and whilst agitation during cooling and spraying, or turning over the bottles has been tried as a means of prevention, none of these measures has been completely successful. An automatic steriliser can be used with bottles which are sealed with crown corks, but swing-stoppered containers must be processed in separate tanks of suitable sizes, being sterilised in their crates. Some plants of this latter type are fitted with a device which will close the stoppers without opening the tanks.

One successful plant is automatic in action and capable of dealing with 300 to 1,000 gallons of milk per hour. It is provided with an automatic loader arranged so that obstructions due to fallen or broken bottles stop the device until matters have been rectified while processing is carried on undisturbed. Carriers are provided into which the bottles are loaded, and these travel upwards through a warmed, hooded section of the apparatus into the water tank. This tank, which is usually duplicated at the opposite end of the machine, provides a water seal which maintains steam pressure in the central closed holding tank where the bottles remain for 30 minutes. They then pass through the second hot water seal into a cooling tank, meeting a gradually-cooling stream of water as they move forwards. Air cooling is applied at this point and finally, the bottles, totally submerged, travel through a tank of cold water maintained in an overflowing condition in the base of the apparatus. The feed and discharge points of the plant can be placed at any convenient point. Fig. 54 shows a modern plant of this type.



By courtesy of R. Webster, Ltd

FIG. 54. Milk sterilising plant.

Bottles of sterilised milk are sometimes cooled by means of a cooling tunnel, gradually reducing temperatures being provided. Bottles in their crates travel through this tunnel and are cooled by a combination of atomised water and air. The final milk temperature is within 10 degrees of the mains water employed. No refrigeration is required as the milk, having been sterilised, is, or should be, free from micro-organisms. While cooling is in progress the external surfaces of the bottles are thoroughly washed while they can be dried, if desired, by means of a thermostatically-controlled air draught. If milk is steamed under pressure, the final product should be sterile, but some methods of processing allow spores of thermoduric organisms to remain unhurt, causing the production of acid and gas which eventually renders the milk unmarketable. On this account, clean raw milk is essential for sterilisation. The bacterial content of sterilised milk at the time it leaves the plant should at no time exceed 10 organisms per millilitre, but it should be noted that recontamination can ensue if the cork portion of the crown cork used for sealing is dirty or if the rubber on the swing stoppers is of poor quality.

All plants should be provided with recording thermometers and thermostatic valves as by their use it is possible to control and record the entire process.

Sterilised milk does not require any cold storage or refrigeration of any kind, which is of considerable advantage to the operator. The cleansing of the bottles is extremely important and it should be noted that the container used for sterilised milk is one of the most difficult to clean on account of its narrow neck. Washing machines should be provided with high-powered jets and detergent strengths should be carefully watched while final treatment should be sterilisation with steam as the hot milk can be readily filled into hot bottles. Recontamination of the milk by an unclean bottle must be avoided at all costs.

Certain points in treatment require to be carefully watched. The homogenisation pressure and the temperature of the milk during this process are important, otherwise the cream may clot within 12 to 24 hours of processing, forming hard lumps in the necks of the containers. Quick cooling after sterilisation is essential in order to prevent the formation of any milk skin due to atmospheric exposure after treatment. Brown-coloured milk caused by the caramelisation of the milk sugar is due to delay in handling after bottling, slowness in attaining sterilisation temperatures, excessive temperatures and periods of heating, atmospheric cooling and delay in water cooling. Off-flavours or reduced keeping qualities may be experienced and are often due to heat-resistant organisms. In such cases, variations in time and temperature are necessary, and once again the necessity of a clean milk for processing is emphasised.

It is not practicable for the small operator to sterilise milk efficiently unless supplies can be obtained already clarified and homogenised. The apparatus necessary for subjecting milk to such treatment is expensive and cannot be installed profitably in small dairies. Sterilised milk possesses no cream-line and is generally retailed at a slightly higher price than many other types, a fact which may retard sales in certain instances.

(4) HOMOGENISATION. "Cream-line" pasteurised milk can never be re-mixed in proper proportion so that the lower levels

of milk in any bottle contain their normal quota of cream. The housewife's claim that homogenised milk has a rich creamy taste throughout its bulk and that it improves the flavour of tea and other beverages, has assisted to improve the sales of milk so treated, a 25 per cent. increase occurring in many instances during the last few years. Pasteurised milk may quite falsely be judged on the cream-line exhibited and one advantage of homogenisation is the absence of any cream-line, rendering such false judgment impossible. There has been, and in some plants there still is, one serious drawback to this process. A periodic tainting of the product by an oily or metallic flavour may be introduced during processing. Innumerable experiments have been carried out to eliminate this defect and it is now possible to prevent such tainting by employing some type of stainless metal for all parts in contact with milk. When the public realises that lack of cream-line does not necessarily mean lack of cream, the sales of homogenised pasteurised milk should speedily increase.

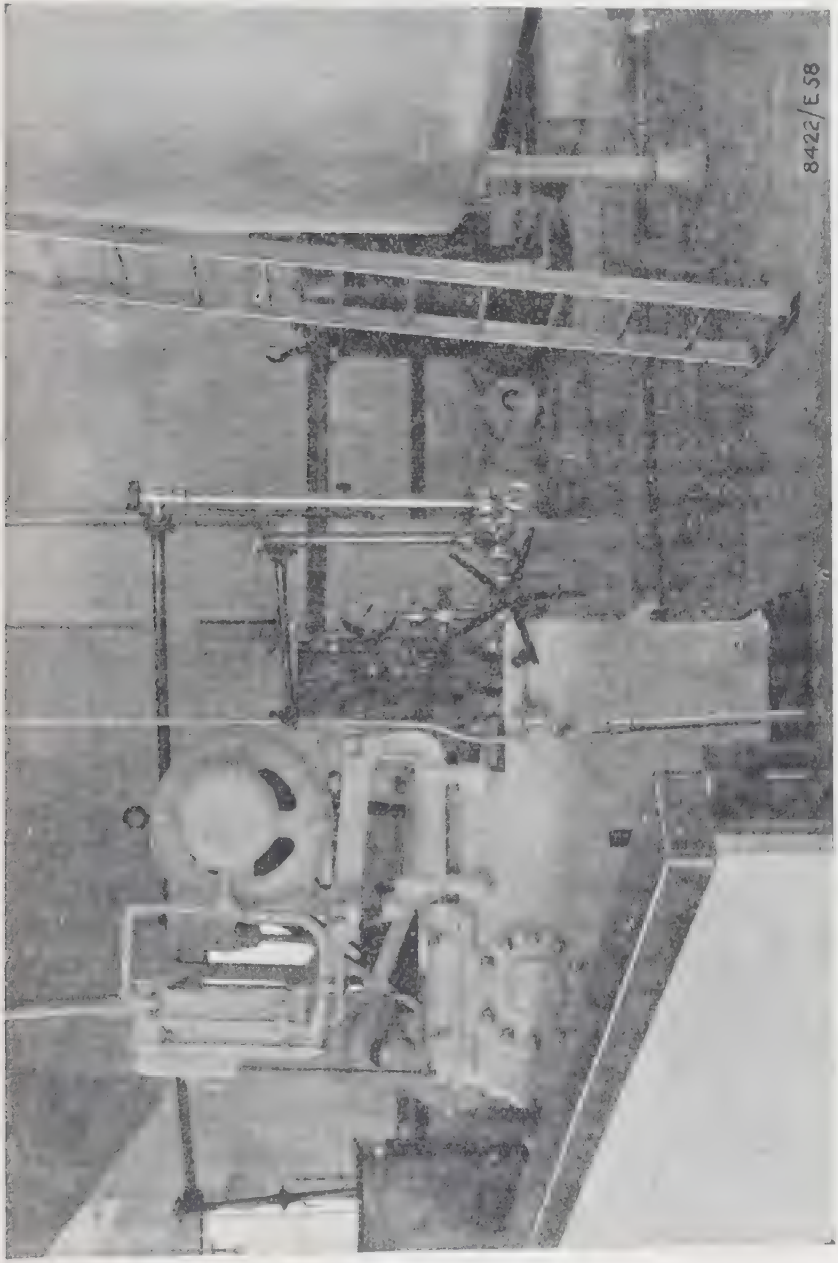
The first experiments in homogenisation were made in France by Marix and Julien in 1892 and by Gaulin in 1899. In 1904, the latter person patented the apparatus in this country and the employment of this process has become indispensable to both the dairy industry and the food trades. Schrader, in 1912, made many experiments with the process which added considerably to available knowledge. Sterilised milk has been homogenised from its inception for reasons already mentioned on p. 173, but the application of the process to milk prior to pasteurisation followed at a much later date.

During homogenisation, the fat globules contained in milk are subjected to an emulsifying process, being reduced to such fine proportions that the distribution of fat throughout the liquid is completely uniform. The treatment gives an apparently increased creaminess to milk owing to a greater surface of fat which is introduced to the palate. When milk has been homogenised, cream globules will not return to their normal size for some considerable time. The process causes no diminution of bacterial content, no destruction of pathogenic organisms, nor any change in the chemical composition of milk. In other words, it is an entirely commercial process. Cold milk can be homogenised but, to obtain satisfactory results, the liquid should be heated before treatment, in order to reduce viscosity.

One point regarding this type of milk must be noted. If it is allowed to stand for any length of time, a ring of sediment frequently forms at the base of the container. This appears similar to very fine dirt or grit mixed with some of the milk solids. Slides prepared by the Breed method show that this slime consists largely of leucocytes and epithelial cells. In milk which has not been homogenised, these cells are, to a large extent, carried to the surface with the cream, but in the homogenised product, the lack of fat globules as such allows them to settle at the base of the bottle as sediment. A similar phenomenon has been noticed in connection with sterilised milk (see p. 173). There is no correlation between the homogenisation pressure and the formation of sediment, this latter being most pronounced when milk has stood for 24 hours. The quantity noticeable always appears to be the same, irrespective of the pressure employed and, in some instances, milk is filtered to remove the sediment after treatment has been completed.

Milk is generally homogenised following a primary heating before it is pasteurised, receiving further heating before it passes for final treatment. The process is usually carried out at a temperature of 140° F., the heat generated during processing raising the milk temperature to the level required for final treatment. Heated milk is forced through a small valve against a hard surface, being subjected to a pressure of 2,000 to 2,500 lbs. per square inch. The fat globules were formerly broken up by forcing them against an agate, but the valves are now constructed of alloy steels and are of various types, according to the ideas of the manufacturer of the apparatus. The normal fat globules are broken down into minute particles, due to their passage from a region of high pressure into a low pressure atmosphere, plus the action of the hard surface against which they are required to impinge. The machine's natural suction draws milk inwards and it passes to cylinders whose inlet valves close on the pressure stroke. The apertures through which the liquid is forced are extremely minute, in many cases possessing a diameter of only $\frac{1}{10,000}$th of an inch. The outlet valve may be adjusted to supply any pressure required, but, in the case of milk, this pressure is normally that already indicated. The valve is spring-loaded with a heavy coil spring between the adjusting screw and valve disc. This permits the valve to be released under excessive pressure and to return to its normal position.

All parts of the apparatus coming into contact with milk should be constructed of acid-resistant, stainless steel, while



By courtesy of the Brush Electrical Engineering Co., Ltd.

FIG. 55. "Brush" homogeniser (capacity 500 gallons per hour).

piping should afford easy accessibility for cleansing purposes. Homogenising machines are heavily constructed to withstand the high pressures involved and can be obtained to treat any quantity of milk up to 1,250 gallons per hour. As these plants are expected to carry out strenuous work in a successful manner, they should receive careful attention if they are to possess a long, active, trouble-free life. Fig. 55 illustrates a modern type of homogeniser.

Homogenised milk is of particular use in hospitals and other institutions where the practice of "skimming" supplies after delivery is suspect. Its greatest recommendation is probably its digestibility. In many cases, infants cannot retain milk in their stomachs and homogenised milk will be found to be of the greatest value, as it is easily assimilated.

(5) IRRADIATION. This method of treatment for raw or pasteurised milks, although still in its infancy, has already been practised commercially in this country with some success. The process consists of the extremely short exposure of a thin film of milk to the action of rays from a mercury-vapour lamp or other reliable source of ultra-violet irradiation. Wavelengths of light rays are usually expressed in terms of millimicrons, the standard employed being termed an Angström unit. One millimicron is equivalent to 10 Angström units. Ultra-violet rays are invisible rays of the spectrum possessing the shortest wavelength, and the wavelengths of rays used for milk irradiation vary from 2,300 to 3,100 Angström units.

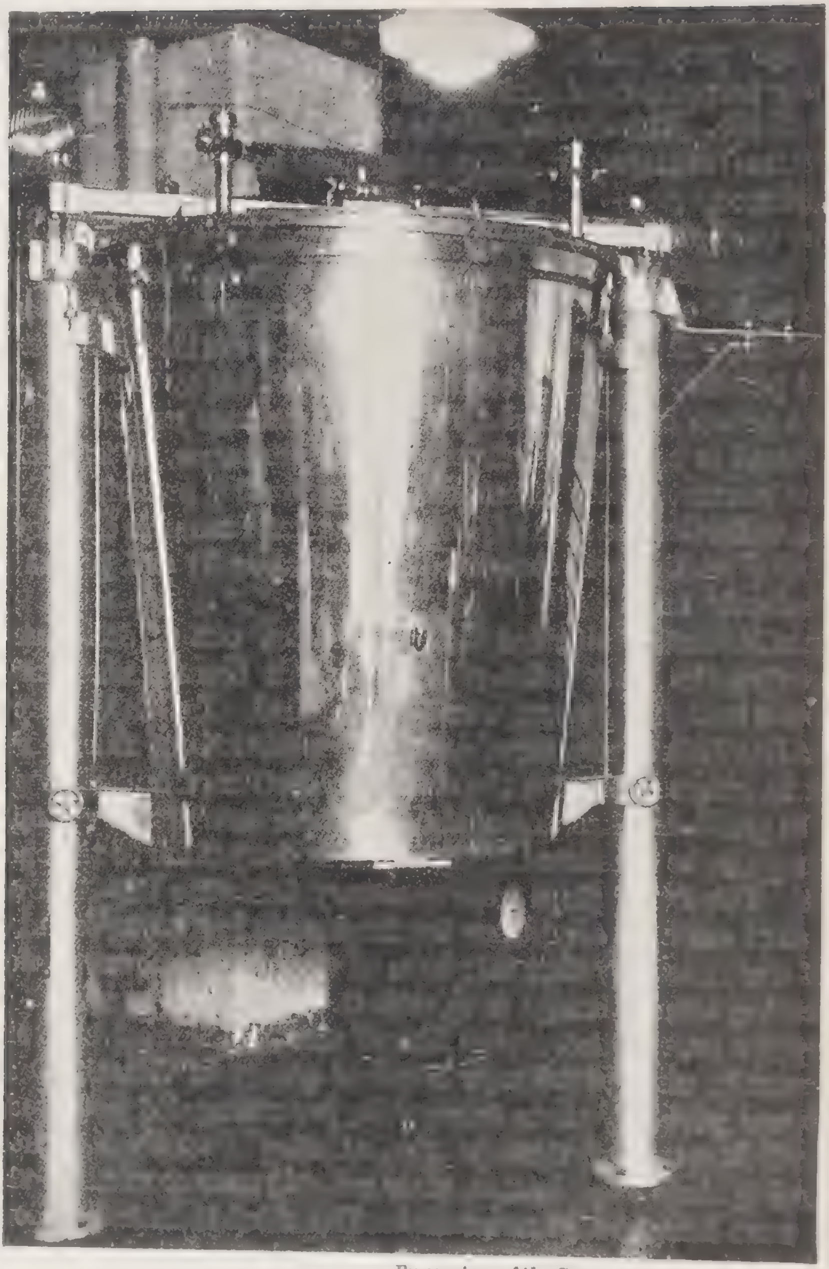
The primary object of this process is to improve the food value of milk without diminishing the nutritive value already present. Steenbock and other investigators have demonstrated that milk develops anti-rachitic properties when exposed to ultra-violet irradiation, by an increase in its vitamin-D content. The vitamin-D content of irradiated milk is dependent upon the natural vitamin-D content in the liquid prior to treatment, upon the amount of activatable substances present and upon the conditions under which it is exposed to irradiation. When consumed in its customary quantities, this type of milk gives adequate protection against rickets in infants and tooth decay in adults.

Rickets is a disease commonly present in children of the poorer populations of our large cities and towns. Although its causes have not been definitely ascertained, it is known to be a deficiency disease, possibly due to faulty feeding or faulty assimilation, lack of sunlight or fresh air, or a combination of these faults. Attacks by this disease are insidious and often overlooked. Persons of any age may suffer, especially after long illnesses, but the greater proportion of children are attacked during their second year of life. The disease affects the whole body and its various functions, changes in bone structure being of the greatest importance.

The part played by sunlight is closely allied to the question of food deficiencies. The disease is unknown in tropical regions, while in the earth's temperate zones, cases are more prevalent in winter than in summer. The position was clarified when it was found possible to render foodstuffs anti-rachitic by exposing them to the action of ultra-violet rays. A substance named *ergosterol* was found to be present in fats and this substance, by irradiation, can be converted into vitamin D. Ergosterol is present in the fat which underlies the skin of both humans and animals and, by the action of sunlight, is converted into vitamin D and passes into the animals' milk.

Once it was established that irradiation was of assistance in improving the food value of an article, it became necessary to discover how the process could be applied. Dr. G. C. Supplee of the Dry Milk Company of America has carried out much pioneer work in connection with the direct irradiation of milk during the last 10 years and has demonstrated that a measurable vitamin-D potency can be generated in the liquid in proportion to the energy input. Two other steps were necessary following this discovery. The most suitable conditions for irradiation had to be found and proof was necessary that this form of vitamin D was successful in protecting human beings from rickets.

Supplee proved that a thin film of milk which received a short exposure to ultra-violet rays acquired plenty of vitamin D and, what was probably more important, processing did not produce any off-flavours or damage the existing vitamin-A content. Following these experiments, more reliable sources of ultra-violet light were found to be necessary. The chief technical difficulty was that the older type of ultra-violet ray lamp failed to maintain a constant output of rays and, on this account, special high-efficiency lamps had to be devised. Concurrent with Supplee's experiments, Hess and Lewis showed that carbon-arc irradiated milk, produced according to the conditions prescribed by Supplee, gave complete protection against rickets in infants. In addition,



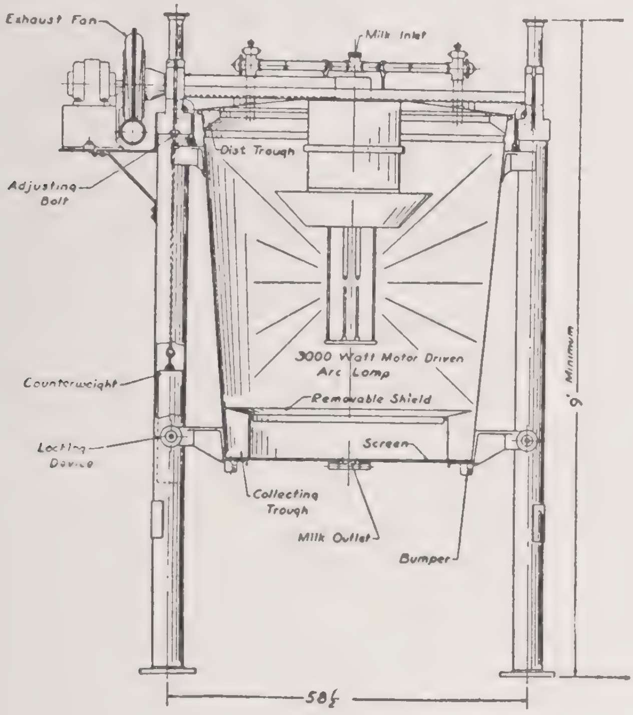
By courtesy of the Creamery Package Co., Ltd

FIG. 56. C.P. milk irradiator.

it was found that irradiation of the liquid exerted a bactericidal action.

There are several methods of treatment. When the *Scholl* *process* is employed, milk is irradiated in a water-cooled chamber, ultra-violet rays being provided by means of a quartz-mercury-vapour lamp fixed 3 inches from the milk film. The *Scheidt process* arranges irradiation in a different manner, milk travelling upwards to the summit of a quartz tube. Ultra-violet rays, provided by means of a high-tension current, are passed through a tube containing argon gas.

The *C.P. process* is an adaptation of the Steenbock method.



By courtesy of the Creamery Package Co., Ltd.

FIG. 57. C.P. milk irradiator (section).

The apparatus is cylindrical in form, milk being fed at a steady, pre-determined rate to a high level distributor trough, from which it flows in a thin film, approximately one-third of a millimetre in thickness, over the inner surface of the cylinder. As the source of irradiation, a carbon-arc, is centrally fixed, and as the cylinder provides a uniform distribution of rays together with a centrally fixed light, all portions of milk receive an equal exposure and are uniformly activated. The cylinder walls prevent any waste of light, render the use of shields or reflectors unnecessary and afford protection to the operators. The process provides maximum capacity in small space, and the apparatus is economical in the use of power and in labour costs, the carbon-arc lamp operating at 50 volts with 60 amperes across the arc. The advantages of this apparatus are that radiation at full power is instantly available, its character and intensity being constant. The carbon used is the type best adapted for the purpose and the ultra-violet output of the lamp is ample for large-scale production. The milk is irradiated without any change in flavour or alteration to the existing vitamins.

The control of the rate of milk flow is effected by using a positive fixed-capacity pump, the current to the lamp being regulated by means of an automatic control device which compensates for any change in line voltage. Plant operation is indicated by means of a recording instrument which shows amperage consumed, operation of the supply pump and duration of run. The irradiating cylinder is mounted on brackets, which slide on supporting columns, and is balanced by means of counterweights. It is constructed of tinned copper or stainless steel, the latter being preferable, and is easily cleansed. Milk takes approximately 5 seconds to flow from top to bottom of the canister, being collected in a trough fixed immediately above the wire gauze at the base of the apparatus. The liquid is exposed to the lamp's rays for approximately 5 seconds, the safety margin being sufficient to prevent the process producing any detrimental changes. An extractor is provided to ventilate the interior of the canister.

The *Cherry-Burrell system* employs an apparatus in which a measured quantity of milk is allowed to flow downwards over a surface exposed to carefully controlled ultra-violet rays. A positive-metering pump distributes the milk over the irradiated surface and is arranged so that the flow is stopped should the light be extinguished. If multiple lamps are employed and one lamp becomes defective, all the remaining lamps are switched out and the pump ceases to work. This prevents milk passing through the apparatus without being irradiated. The surface over which the milk flows is designed to act also as a cooler so that the liquid may be cooled while irradiation is proceeding. Certain technical safeguards are provided. Any change in current voltage would result in over- or under-irradiation. A recording ammeter is therefore provided equipped with a second pen to record the current operating the motor of the measuring pump. By comparing the two records, it is possible to ascertain that milk is flowing at the correct rate and that the arc lamp is burning with correct intensity. A recording ultra-violet ray meter is provided to show the degree of radiation efficiency and the action of this instrument is comparable to that of a recording thermometer.

A method of increasing the vitamin-D content of milk has been developed in Germany and the apparatus consists of an aluminium cylinder approximately 7 feet in length and 2 feet in diameter which houses a quartz spiral tube roughly ½ inch in internal diameter. This spiral is just over 125 yards in length and the interior of the whole cylinder and the coil is flooded with ultra-violet light from eight straight ultra-violet tubes. The apparatus has a capacity of 100 gallons of milk per hour. Experiments with this apparatus are reported as having been extremely successful in increasing the vitamin-D content of milk, and it is also claimed that cold milk is pasteurised at room temperature during the irradiation process. Difficulties have always been experienced on account of the low penetrability of ultra-violet light into milk, and it is suggested that the length of tubing employed overcomes this state of affairs. One plant has been installed in Germany which consists of three units capable of treating 300 gallons of milk per hour. Each unit consists of 50 straight quartz tubes, each just over 2 yards long which are placed vertically and joined together in series by means of plastic tubing. The three units are operated in parallel and are housed in a metal cabinet which is flooded with ultra-violet light from a number of tubes running the height of the cabinet and which are placed between the rows of milk tubes. The milk flow is maintained by means of an electric pump. A narrow waveband is employed for pasteurisation and a rise in temperature of approximately 9° F. occurs in the milk during its passage through the apparatus. Little difference was noticeable in the flavour of the liquid after treatment.

It is possible to employ an ordinary surface cooler for irradiation purposes but in such cases it is essential that only a very thin film of milk should pass in front of the rays in order to obtain full benefit from the process. The lamp should be properly shaded to concentrate the rays on the surface of the liquid being treated. As short wavelengths, the most useful for irradiation purposes, are quickly absorbed, correct distance of the lamp from the milk film is essential. Over-exposure to the action of ultra-violet rays leads to oxidation of the milk-fat globules, this oxidising action being completed in 11 seconds.

Rooms in which irradiation apparatus is housed require special consideration. All air employed for ventilation purposes should be drawn through dust filters. Preferably, such rooms should be air conditioned, while fans should be provided to remove all products of combustion from lamps together with any ozone which is produced. Eye protection for the operators is of extreme importance as constant exposure to the rays will lead to painful irritation of the conjunctiva of the eyes. It is advisable to provide processing rooms with special windows of darkened glass in order to permit the operator to make any necessary observations without direct exposure to the lamp rays.

Milk may be treated either in its raw state or after pasteurisation, but it is always preferable to carry out the treatment at as low a temperature as possible, prior to pasteurisation. Milk irradiated in this manner does not lose its potency during storage or subsequent treatment.

The benefits derived from irradiation are *final cleanliness of milk* and *increased food value*. At one premises treating milk in this way, it is reported that the average count is constantly maintained below 1,000 bacteria per millilitre. These satisfactory results are, of course, assisted by hygienic methods of production. All utensils are sterilised by means of the mercury-vapour lamp, being subjected to a short exposure by the rays after a preliminary washing. To demonstrate the effectiveness of the method, an experiment was carried out by the National Institute for Research in Dairying, Reading, with an artificially infected sample of milk. This was irradiated, the treatment affecting a reduction of 98·5 per cent. in the number of organisms present. It should be remembered that where the bacterial content of a sample of milk is low, it is difficult to reduce this number still further.

A further benefit to be derived is the increase in vitamin-D content. Experiments have shown that vitamin D present in irradiated milk is much more active than is the case with that found in cod-liver oil, while, if the process is efficient, the remaining food values of milk are not impaired in any way, nor is the creamline affected or the taste altered.

American and German investigators have proved that properly irradiated milk is of great value in the treatment of rickets, and irradiation seems to be an ideal method of treating either raw or pasteurised milk. The process has not, up to the present, made any great advance in this country, but in Canada and the United States of America, sales of this class of milk are steadily rising. Increasing sales are almost certain to follow here within the next few years, when the purchasing price should be little more than that of ordinary milk.

(6) VACUUM PASTEURISATION. A method of vacuum pasteurisation has been introduced to the dairy industry of America within the last few years. This is described as a system of pasteurising and conditioning liquids, particularly milk and cream. The important object of the process is to provide an improvement in the flavour of milk in conjunction with effective treatment. It is stated that this method augments and magnifies the volatalising effect of normal pasteurising and cooling processes in relation to off-flavours which are due to feeding materials and other influences. It is claimed that exhaustive tests of the process have been made and fifteen installations in dairy plants have been tested for 2 years with highly successful commercial results.

The principle of vacuum pasteurisation is mixing milk under compression, this being immediately followed by sudden and spontaneous expansion in a finely divided state within a chamber of reduced pressure. The separation of treated milk and its contained off-flavours in the form of vapours provided by the sudden transition from a state of compression to a state of expansion is maintained by heating the walls of the separating or vacuum chamber. In addition, the instantaneous pre-cooling effect upon the product accompanying its expansion within the vacuum chamber is described as an important factor in preserving the desirable body characteristics of the liquid, even when inordinately high pasteurising temperatures are utilised, such as could not be normally employed without being detrimental to the product.

The process provides the means for heat treatment of milk within the conventional pasteurising range and at particularly higher temperatures, *i.e.*, above normal "Flash" range and within the sterilisation limits of 200° to 250° F. or higher. In other words, pasteurisation at high temperature, that is, above the boiling point of the fluid at normal atmospheric pressure, is accomplished with vacuum pasteurisation.

CHAPTER X

BOTTLES, BOTTLE FILLERS AND WASHERS

Bottles. Milk which has been efficiently processed and cooled needs careful treatment, and *milk bottles*, their filling and washing require consideration. The delivery of milk in glass bottles was almost unknown in this country until the sale of sterilised milk commenced, and for many years afterwards the ordinary type of milk bottle, which is so familiar at the present time, was seldom seen except when employed for the sale of humanised milk for infants. The quantity now sold in bottles has assumed huge proportions, and the employment of sterile bottles as containers for processed milk is an added safeguard against contamination both during delivery and when stored in the consumers' homes. While bottles add considerable extra weight to the distributor's load, and although losses through breakages, carelessness and theft are not inconsiderable, their employment is certainly advisable from a public health viewpoint, always provided they are thoroughly cleansed and sterilised between each outward journey. During the last few years a lighter type of milk bottle has been evolved which is extremely durable and possesses a longer active life in spite of its decreased weight. The choice of bottles is important. They must be *strong* to withstand frequent changes of temperature when sterilised, the glass must be *perfectly clear* since the appearance of their contents might otherwise be spoiled and the cream-line undetectable, while the *neck* of every bottle should be free from internal crevices to allow easy cleansing. Bottles are manufactured in two main types but in a variety of shapes, either wide-mouthed for raw or processed milk or possessing a narrow neck for crown corking or fitted with a wire swing stopper, for sterilised milk. Bottles with wide mouths and capped by discs are most unsatisfactory. Invariably, the rim on the neck is used for handling and may become grossly contaminated, while it is easily filled with loose milk, and afterwards sealed with a disc taken from the roundsman's pocket. All bottles should be of sufficient size to contain the full measure of milk they are designed to hold.

Experimenters in Canada, carrying out research work on riboflavin, have asserted that bottles made from red or green glass are preferable to the clear variety. It has been discovered that the exposure of milk to sunlight causes it to lose its riboflavin content fairly rapidly and bottles of coloured glass would ensure that the liquid retained its full nutritional value for a longer period. It would appear that not only the design and constrution of milk bottles but also the materials from which they are made might be usefully the subject of further research and study, particularly as regards the effect of such materials upon the nutritional value of the liquid they contain.

The approximate sizes of milk bottles are set out in Table 3 below.

TABLE 3

Size.	Greatest Diameter.	Height.	Weight.	
	Inches.	*Inches.*	*lb.*	*oz.*
Quart	4	10	1	15
Pint	$3\frac{1}{8}$	$8\frac{1}{2}$	1	2
$\frac{1}{2}$-pint	$2\frac{1}{2}$	$6\frac{7}{20}$		$12\frac{1}{2}$
$\frac{1}{3}$-pint	$2\frac{3}{10}$	$5\frac{1}{2}$		$11\frac{1}{3}$

The *sealing of the bottles* is extremely important and some mention of this process has already been made on p. 128. *Waxed cardboard discs* are quite commonly used for sealing purposes, large quantities of milk being delivered in bottles sealed in this manner. This type of seal cannot be considered satisfactory. Unless of high quality, it may harbour bacterial spores which will obtain entrance to the milk when the disc becomes saturated. Dust or rainwater readily accumulates upon its upper surface and will contaminate the lip of the bottle neck over which the liquid must be poured, or even gain entrance when the disc is removed. If discs are employed, they should be clean when affixed, should efficiently prevent the escape of milk and, during sealing, no milk should be splashed on their surfaces.

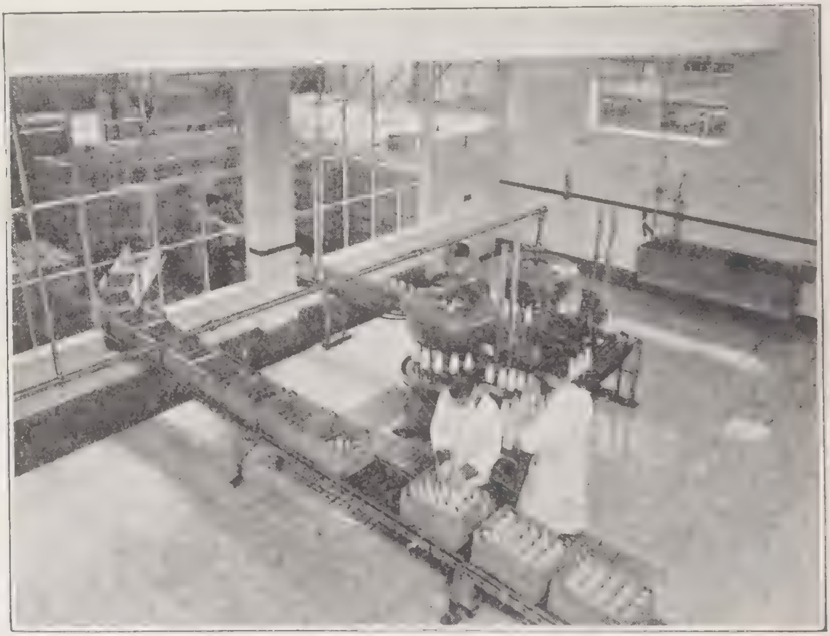
The ideal seals for processed milks are aluminium caps or crown corks. *Aluminium caps* have achieved considerable popularity not only in this country but also abroad. Before the last War, approximately 90 per cent. of the milk sold in Denmark, Sweden and Holland was capped in this way. It has been estimated that over 100,000,000 of these caps are used annually in this country, and it is safe to state that their employment is likely to increase considerably. This form of seal possesses several advantages. The lip of the bottle is covered, preventing contamination, while this type of cap is easily removed by tearing the tag provided. Ease of removal prevents spillage of milk which so often occurs when discs are employed. Aluminium caps form an ideal seal, but their choice is important, preference being given to one which cannot be removed and replaced as is possible with some types. Such caps are germ-proof, air-tight and non-absorbent and they can be quickly affixed, and this type of closure has received official approval for use with all designated milks. Many distributors seal their bottles with *crown corks* which are cramped on the necks of the containers, forming an extremely efficient and suitable seal which is not readily removed and cannot be satisfactorily replaced.

BOTTLE FILLERS AND CAPPERS. Bottle filling should be carried out with a minimum of disturbance to the milk and with an entire absence of foaming. On no account should the milk be pumped to the bottle filler.

In the majority of processing plants, filling and sealing of bottles is carried out automatically by means of machinery. *Bottling machines* in a variety of sizes are procurable for this purpose, many handling up to 100 pint or 60 quart bottles per minute, *rotary apparatus* being usually employed. The bottle enters at one point in the circumference of the machine and, as it revolves to its starting point, is automatically filled with the correct quantity of liquid. The cooled milk flows by gravity to the receiving bowl of the filling machine, the pipe-line through which it travels being provided with a flow-regulating valve. This pipe-line must be kept as short as possible. On leaving the filler, the bottles pass to a sealing apparatus where they are either disced or capped, and after sealing is completed they are crated. The crates are then removed to one or more refrigerated rooms where they are stacked in a temperature of 40° F. or below in order to inhibit bacterial growth.

There are two main types of bottle filling machine, each of which may possess minor variations in design according to the ideas of the manufacturer. In one type, milk flows by gravity into bottles automatically raised and pressed against the filler valves. With the other method, bottles are filled by creating a vacuum inside them. Overfilling should always be avoided, an air space being left between the upper surface of the milk and the cap. This space provides for expansion of milk on account of changes in temperature. If bottles are overfilled, the liquid may be forced past the edges of the seal and this leakage will attract flies and domestic animals.

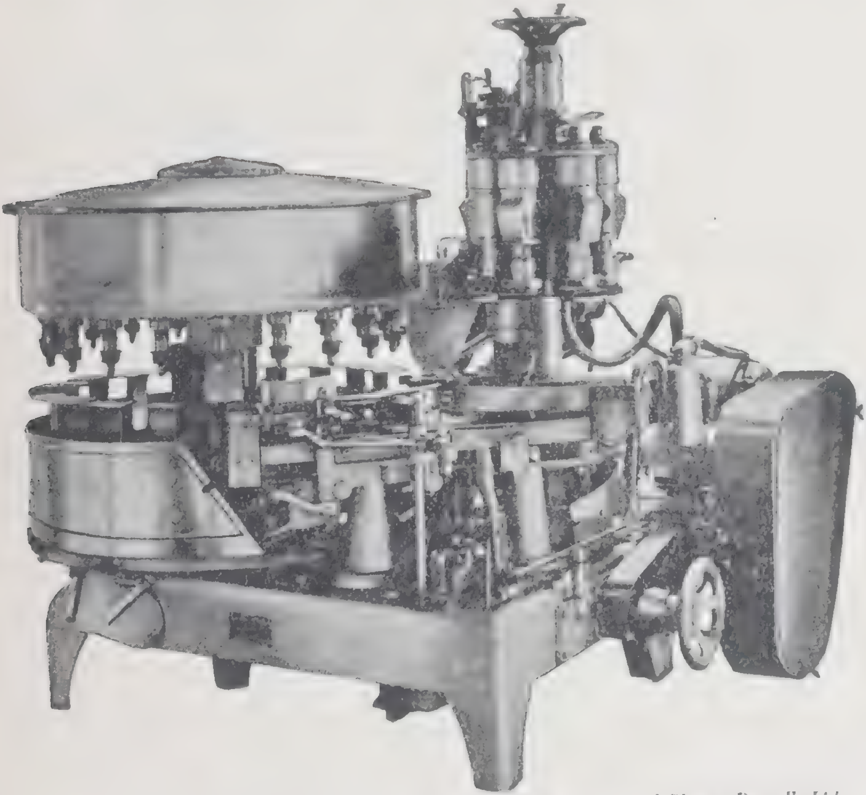
Sterilised bottles travel by means of a conveyor from the washer and are fed into the filling machine either by hand or, more usually, by means of an automatic device. If hand feeding is employed, the operator should invariably remember that the bottle will be nearly sterile and should be handled carefully by the neck and not its lip, in order to prevent any danger of hand-borne contamination. The automatic sealing apparatus is synchronised with the filling process so that as the bottles are filled, a minimum of time elapses before they are finally sealed.



By courtesy of Cherry-Burrell, Ltd.

FIG. 58. Bottling room of modern dairy showing crate conveyor and bottle-filling and capping machine.

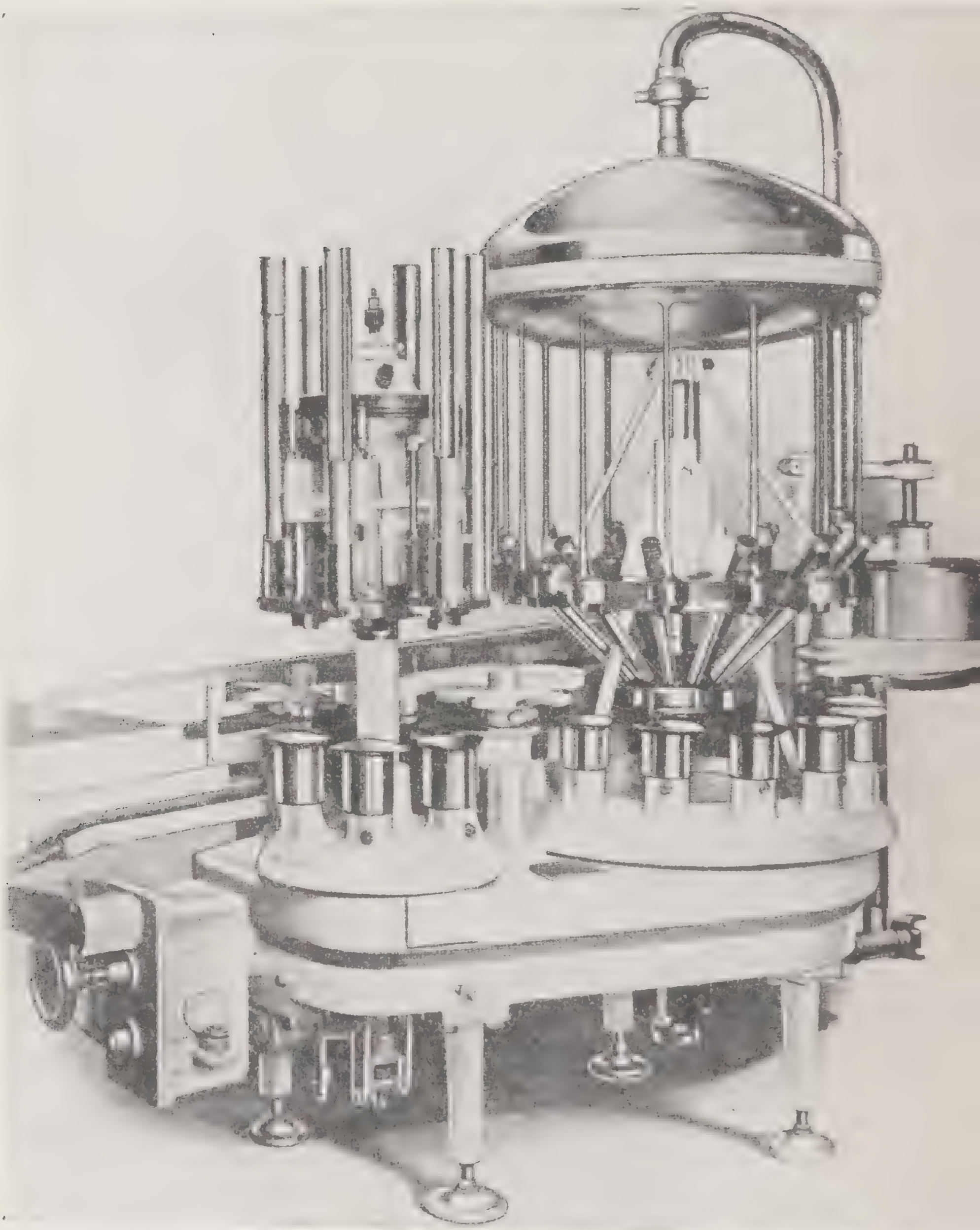
Certain points in design require to be noted. Milk from the cooler is fed into the receiving bowl situated above the filler valves. This container should be constructed of material which will allow easy cleansing and should possess no corners. It is extremely important that a suitable, firmly-fixed cover should be provided, as otherwise re-contamination of the milk may ensue. The design of filling valves and measuring devices is important. They should be easy to dismantle and the bore through which the milk is discharged to the bottle should be free from angles and bends in order to simplify cleansing.



By courtesy of Cherry-Burrell, Ltd.

FIG. 59. "Milwaukee" bottle-filling and capping machine.

Many types of *combined filling and capping machines* are available to the plant operator. They vary little in principle or design and carry out their work admirably in spite of the constant usage they undergo. They should be fast, simple, reliable and economical in operation and the design of capping apparatus should ensure that every cap is tight and leak-proof. There should be complete freedom from stoppages due to jamming of caps or to breaks in the foil, while the apparatus should be easy to cleanse and sterilise. In addition to these advantages, a compact

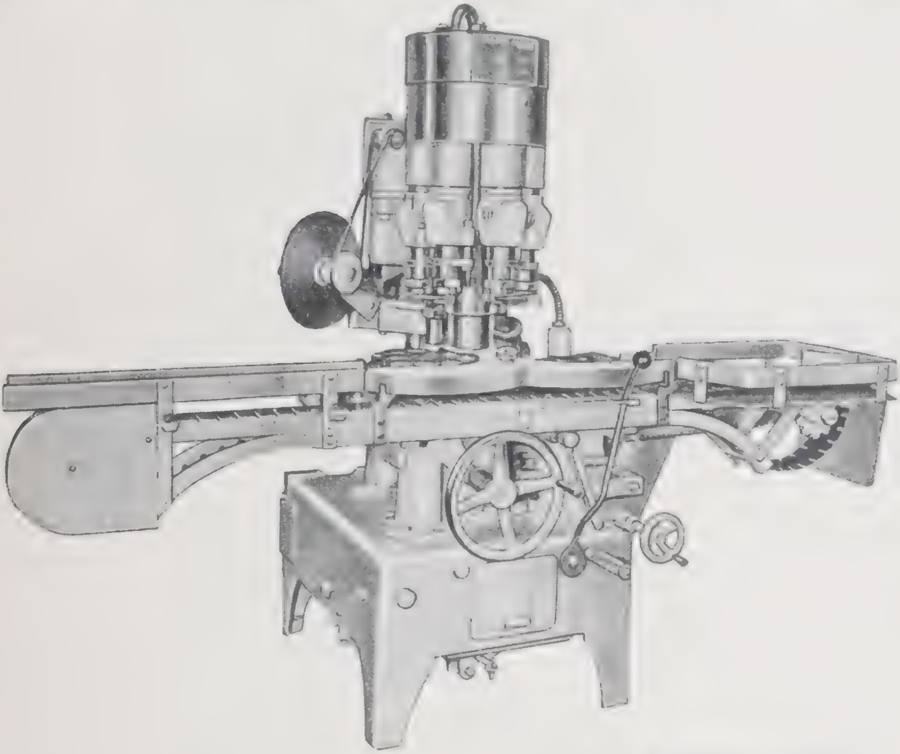


By courtesy of the Albro Fillers and Engineering Co., L

FIG. 60. "Albro" milk bottle filler and capper. (14 head—600 gallons per hour).

design is to be desired which will provide for economy in space
The receiving bowl should possess either a stainless steel o
porcelain-enamelled lining while the filling head should be suc

as will ensure that the process is frothless. Vacuum fillers possess the advantage of being valveless, filling operations being carried out without the operation of moving parts. Such plants will not operate on chipped or broken bottles, are usually dripless and do not waste milk. Many machines of this type will continue to operate even if the vacuum fails, the principle of operation being a combination of gravity and vacuum.



By courtesy of Alka, Ltd.

FIG. 61. "Alka" bottle-sealing machine.

A short description of some of the more important types is given below.

The *Milwaukee* machine is constructed in various sizes estimated to fill and cap from 12 to 60 pint bottles per minute. Valve filling is employed, and any size of bottle may be filled and capped. The machine obtains its motive power from a small electric motor and the action of filling and capping is entirely automatic. The *C. P. Davis Rotary* will deal with 24 to 66 pint bottles per minute without spillage or breakage. Valve action is again employed and a porcelain-enamelled milk tank is fitted.

The action of the apparatus is perfectly smooth and automati immediately the electric motor is switched on. The *Gem* is a excellent machine which possesses a maximum filling and cappin capacity. It is entirely automatic and the filling head is designe to give frothless filling while the machine is readily dismantle for cleansing purposes. The *Albro* filler is a vacuum type o apparatus, the filling operation being carried on without the us of any moving parts. It will not operate on faulty bottles and there is no wastage of milk. Operation is by means of vacuum, no valves being employed, and an air-operated bottle lifting platform obviates any crushing of the containers. Low-leve milk feed is provided and all parts in contact with the liquid ar constructed of stainless steel. Standard capacities range fron 40 to 120 pint bottles per minute, and the capping apparatus i designed to affix discs, aluminium caps or crown corks as desired The *Alka* bottle-sealing machine which may be employed i conjunction with any automatic filling apparatus is entirel automatic in action, forming the caps and sealing from 3,000 t 6,000 bottles per hour of various sizes. This type of apparatus which has been incorporated with many existing fillers, is the original capping machine, having been invented in 1914 by Jose Jonsson in Sweden and first imported into this country in 1929.

All bottles after they are filled should receive a final inspectio before they are crated. Any which appear dirty or unsatisfactor should always be removed for further investigation when tim allows.

Bottle Washing. There is a great deal of evidence to sho that pasteurised milk from the cooler which possesses a lo bacterial content and good keeping quality may, after bottling show a large increase in the number of organisms which it contains while the time it will keep may be greatly reduced. Th hygienic quality of the milk when sold is influenced considerabl by the bacterial condition of the bottles into which it is placed If one adds the danger to the consumer through bottles returne from households sheltering persons suffering from transmissibl diseases, the dangers which may arise from improperly cleanse and sterilised containers are obvious. Further, the cleanl appearance of bottles and their contents is a point in the distributor's favour. The aim should be to secure bottles whic have a cleanly appearance and are free from visible dirt o blemishes, while from a public health point of view, it is essential that bottles should be properly washed and be bacteriologically clean before being filled. It should always be remembered that however clean and sparkling a washed bottle may appear, it may still be heavily contaminated with unwanted organisms.

Bottles returned from private houses are generally rinsed or washed before they are returned to the roundsman, but hotels, cafes and business premises are very lax in this matter. Containers from such premises are frequently returned in an extremely dirty condition, with dried-on milk adhering to their internal surfaces. Many will be found to contain foreign material which has accidentally obtained entrance, while quite a number are returned with the discs or caps forced into their interiors. Much time and trouble would be saved if consumers would take the simple steps necessary to protect bottles from contamination and if they would invariably wash or at least rinse them before they are returned to the roundsman. The common practice of standing empty milk containers on doorsteps overnight at the mercy of prowling animals is also to be deprecated.

All bottles which are extremely dirty should be kept apart for prolonged soaking in ½ per cent. caustic soda or dilute hydrochloric acid so that the foreign matters present can be easily removed. The procedure will ensure that the detergent in the washing machine retains its strength for a longer period, while much of the labour of cleansing will be obviated. In many instances attempts to cleanse such receptacles will be uneconomic and they should be destroyed. It must be emphasised that new bottles, after unpacking, require to be thoroughly cleansed before they are used. It is quite a common practice to put such containers into circulation before this has been done.

The large distributors carry out the process in a fairly satisfactory manner but this cannot be said of many smaller operators. Indeed, the methods employed in large numbers of small dairies are totally unsatisfactory. In many instances the bottles receive only a preliminary rinsing followed by a haphazard wash in lukewarm water, are allowed to drain and no attempt is made at sterilisation. To place efficiently pasteurised milk into dirty bottles will entirely nullify the value of processing, and efficient bottle washing is quite as important as the efficiency of pasteurisation or other processing methods. Bottle washing can be undertaken without providing elaborate or expensive machinery if greater efforts are expended on the process to ensure that these receptacles are efficiently cleansed and sterilised.

When bottles are dealt with by hand, they should receive first a thorough washing in cold water, this operation being followed by vigorous internal and external brushing. A similar treatment should be carried out in hot water containing detergent, and then in clean hot water, *steam sterilisation* completing the process. Steam sterilisation is essential when hand washing is practised. Bottles should be packed in crates, mouths downwards, and stacked, crate upon crate, in the steriliser. It is extremely important to ensure that bottles are efficiently treated, as these are the only articles owned by the distributor which are allowed to pass out of his possession and over which he has no control while they remain upon the consumers' premises. If reliable bottles are used, undue breakages on account of steam sterilisation need not be feared. In very cold weather, steam should always be admitted gradually to the steriliser, the bottles being allowed to cool off in a similar manner.

This method of washing and sterilisation is practised by many small distributors and there are a variety of hand-operated washing machines available. They usually comprise a washing tank, rinsing jets and power-driven brushes, and if properly handled, are quite efficient for small outputs.

Of all dairy machinery, it is probable that the greatest developments have taken place in the design of bottle-washing plant. The first machine manufactured for this purpose owed its inception to the introduction of sterilised milk into this country at the end of the last century. Since that time these machines have been developed most ingeniously so that now they are able to deal with an enormous number of bottles per hour, providing many distinct operations with almost uncanny precision.

There are innumerable types of *automatic mechanical bottle washers* of different capacities to be obtained, but even the smallest size is necessarily expensive. In large plants their installation is essential as, with the exception of the dirtiest bottles which need separate treatment, the remainder can be fed into the machine and will be ejected at the opposite end of the apparatus in a clean condition, ready for filling. Large machines are available which will handle up to 10,000 bottles per hour in a satisfactory manner. It is to be regretted, however, that in spite of all efforts expended by machine manufacturers and by distributors, mechanical bottle-washing still remains the weakest link in large-scale processing, although happily this weakness is being slowly overcome. It is necessary to remember that the efficiency of any bottle-washing apparatus must always be judged by the condition of the washed bottles when the apparatus is working at full pressure as required under commercial conditions. The efficient work of the washing machine is governed by the quality of the water used, the composition and strength of the detergent solution, the previous condition of the bottle treated, the glass used in its construction and the form of the bottle itself. It should be emphasised also that any weakness is not so much due to faulty machine design as to that of carelessness on the part of the operator.

Bottle-washing machines require common-sense management if they are to carry out properly the work for which they are intended. Such apparatus will operate efficiently if it is adequately cared for and, while designed for the work, other factors are concerned if the washing process is to be efficiently undertaken. The most important of these is the detergent solution employed, which must destroy the greater part of any bacteria that are present and remove both these and other foreign matter from the bottles. The type of detergent is important, but of equal importance is its concentration, the manner in which concentration is controlled and its temperature. Relatively high detergent concentrations are required at low temperatures so that if fairly high temperatures in the neighbourhood of 130° to 150° F. are employed for detergent washing, greater cleanliness and freedom from bacterial contamination will be achieved. Loss of detergent through spillage or leakage may be due to faulty design while the solution quickly becomes fouled by milk residues. The properties of a good detergent are given further consideration on p. 218. Another factor affecting efficient washing is the water supply. Not only must water be as soft as possible, but it must also be as nearly sterile as can be obtained. Hard water must undergo a softening process if it is to be entirely satisfactory for washing purposes.

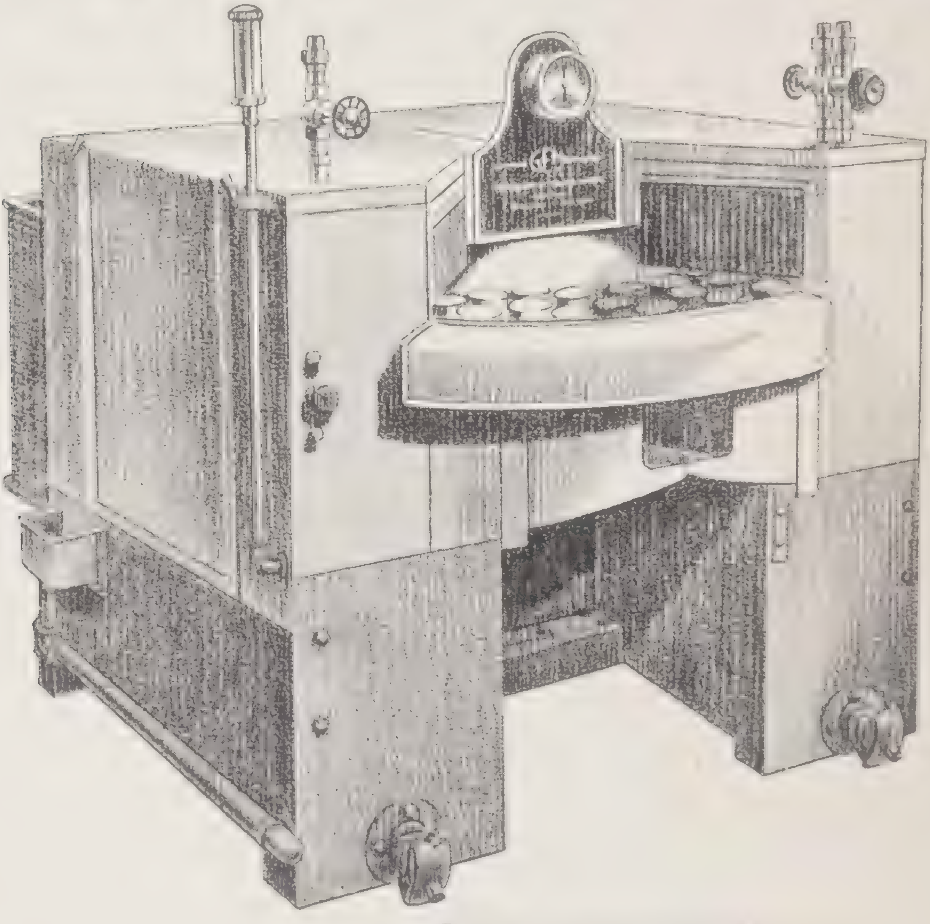
Bottle-washing machines treat bottles in several stages, such treatment naturally varying according to the manufacturers' particular ideas. It is usual to give the bottles a preliminary rinsing in cold water, this being followed by a warm water rinse (90° to 100° F.), the temperature of which is dependent upon weather conditions. This rinse tempers the receptacles and prepares them for washing with 1 to 1½ per cent. caustic soda or other detergent solution at temperatures in the neighbourhood of 140° to 150° F. Several further washings in detergent solution at 160° F. may then be given and the bottles are finally rinsed with hot water at 200° F. Some machines treat the bottles with superheated steam for 20 to 30 seconds, cleansing operations being completed by cooling slowly with jets of water at varying temperatures down to 65° F. unless a hot bottle is desired. A dry bottle is supplied by some types of apparatus if required. In machines which employ neither steam nor boiling water for sterilisation purposes, the efficiency of the operation depends entirely upon the detergent solution used. Detergent solutions can only operate efficiently if the pre-rinsing section adequately removes the larger particles of dirt in the containers, if they are filtered to remove any suspended matter which might choke the jets and if their strength is adequately maintained. Such machines if correctly operated will supply an almost sterile bottle.

A pre-rinsing device to remove all loose milk from bottles before they enter the soaking tanks is commonly found in all modern machines. This pre-rinse should be sufficient to prevent any loose milk being carried forward to the washing and detergent compartments, otherwise the advantages gained which normally provide for a considerable saving in cost of detergent are likely to be nullified. Bottles, after they have been pre-rinsed, are washed with hot water at varying temperatures and this procedure allows higher temperatures to be maintained in the soakage compartments without fear of breakages. The bottles may be soaked for varying periods up to 10 minutes duration in detergent solution, usually caustic soda or one of the many proprietary brands now obtainable, whose strength is automatically maintained during the passage of the containers through the machine They should be given a thorough internal and external brushing which should also include their bases. In passing, it may be noted that there appears to be an increasing tendency to revert to brushes so that completely clean and sterile bottles are obtained. Some distributors maintain that brushing is essential, but obviously this is a matter of individual preference. A continuous spray of water should operate during all washing operations. The bottles may again be washed in hot detergent solution before being finally rinsed with very hot water. They are sometimes sterilised by means of superheated steam, although this procedure is not so common as would seem desirable and, after treatment, are finally cooled. It would appear that too much reliance is placed upon the strength of the detergent solution, a most unwise policy, as this depends, in turn, upon the care exercised by the operator. The cream-line, so important in the estimation of the plant operator, is influenced by the temperature of the bottle leaving the washing machine. If milk is maintained in a cold condition during the rising of the cream, a better cream-line is produced. Bottles leaving the washer may possess a higher temperature than the milk with which they are filled and, owing to the container's bulk in contrast to the liquid which it contains, the temperature of the contents may be raised several degrees, with detrimental effects upon cream-line. It is obvious that the final rinse should be given with the coolest available safe water supply, and for this purpose brine-cooled water deserves serious consideration.

The real efficiency of the apparatus can be judged by the bacteriological examinations of the finished articles, standards for which are set out on p. 242. If a bottle exhibits a high count, it is, in most instances, due to re-contamination, for if the detergent has done its work properly, the container should be almost sterile before it receives its final rinsing. This re-contamination is generally due to contaminated rinsing water although condensed water from bottle carriers and the discharging mechanism is a common cause of this trouble. Additional sources of infection are the water-softening plant if this is used, gelatinous masses swarming with bacteria which may be built up on the jets, infrequent cleansing of the rinsing water tanks and the formation of scale. Controlled chlorination with suitable compounds yielding actual chlorine (10 parts per million) will prove effective in controlling the bacteriological quality of rinsing waters. The use of such chemicals is now permissible.

There are a number of *rotary bottle washers* which are suitable for the small distributor, but these do not possess the large bottle-handling capacity of the soaker- and brush-type machines although they are equally efficient if properly used. They can be operated by one employee as, owing to the rotary principle, the machine is fed with dirty bottles and clean bottles are removed at the same point.

The "*Gem*" rotary apparatus is constructed to handle any number up to 3,600 per hour. It occupies little space, thus being suitable for premises where room is at a premium. This washer is provided with jets which travel for a certain distance with the bottles and then return to their original position, to move forward with the next row. This gives a spraying equivalent to that which would be received by bottles travelling three times the same distance over fixed jets. A pre-rinse is followed by treatment with hot detergent solution, warm-water rinsing and



By courtesy of the Graham-Enock Mfg. Co., Ltd.

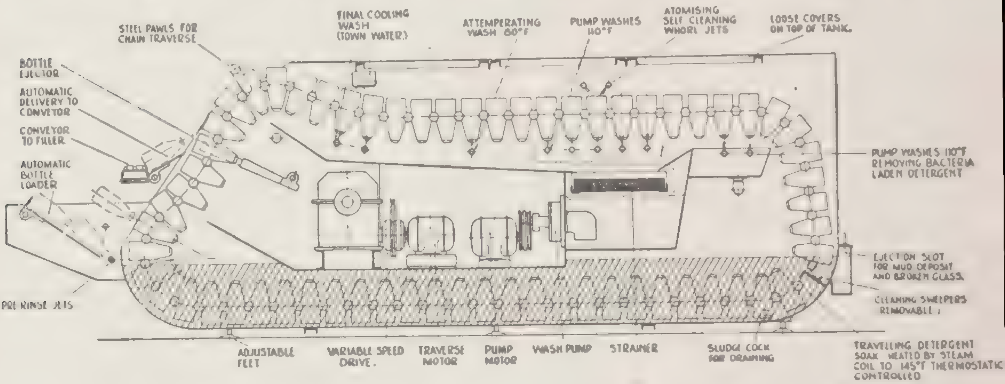
Fig. 62. "GEM" rotary washer.

a final rinse with fresh mains water, the bottles being treated both internally and externally. A temperature recorder is fitted to the solution tanks, temperatures being shown on a dial in full view of the operator.

The "*C.P.*" is a useful apparatus, as it can be operated by one person. Bottles are placed individually in an inverted position in metal pockets and are centred accurately over the various jets. They are given a warm-water rinse, sprayed from solution jets internally and externally, rinsed by hot-water and finally sterilised with steam. Any size bottle can be treated with this apparatus and a preliminary cold-water rinse should be given before treatment is commenced.

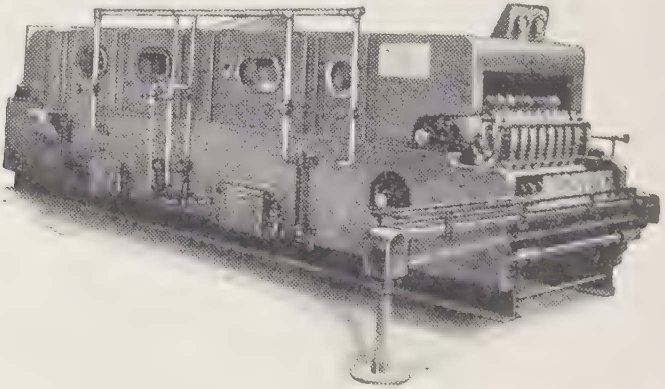
In large dairies, two main types of washer are employed. One is the *spray type apparatus* which possesses, for its size, the advantages of economy of floor space and labour. Once the bottles are placed in the machine, they emerge, after cleansing, at the opposite end, being automatically tipped, neck upwards, on to a conveyor which carries them to the filling machines. The crates pass through a crate washer and are also delivered to the fillers in clean condition. The action of this type of apparatus depends upon the use of detergents to loosen and remove milk solids and destroy any organisms present in the bottles. They pass, in an inverted position, over jets which spray them, inside and out, under pressure. The external surfaces of the bottles are sometimes given a vigorous brushing to remove any dirt which may adhere while usually a final cold water rinse is given to reduce the bottle temperature prior to filling.

The "*A.D.E. Soakwasher*," a section through which is illustrated in Fig. 63, is designed to deal with from 2,000 to 10,000 bottles per hour, each container being given a pre-rinse with warm water under pressure, washing for several minutes with warm detergent solution at 145° F., two pressure washes with water at 110° F. to remove the detergent which are followed by a further five pressure washes at the same temperature. A tempering wash at 80° F. is then given and this is followed by two final clean water washes at mains temperature. Another type of A.D.E. bottle-washing machine has already received mention on p. 132. The "*Dawson*" *Hydro Bottle Washer* is designed to deal with 1,000 to 10,000 bottles of various types per hour. It has a slow, mechanical, intermittent motion with positive centring of the bottles over the jets. There is a gradual rise and fall of washing temperatures which are automatically controlled, dual pressure gauges and thermometers being grouped together on one panel. If desired, hot bottles may be delivered for use with in-bottle pasteurisers and for the reception of milk to be sterilised, in which case steam jets are substituted for the final cold rinse. Adequate filtration of the washing waters is provided and the bottles are fed semi-automatically with positive automatic discharge of clean bottles. The apparatus is illustrated in Fig. 64.


STEEL PAWLS FOR CHAIN TRAVERSE
FINAL COOLING WASH (TOWN WATER)
ATTEMPERATING WASH 80°F
PUMP WASHES 110°F
ATOMISING SELF CLEANING WHORL JETS
LOOSE COVERS ON TOP OF TANK.
BOTTLE EJECTOR
AUTOMATIC DELIVERY TO CONVEYOR
CONVEYOR TO FILLER
AUTOMATIC BOTTLE LOADER
PUMP WASHES 110°F REMOVING BACTERIA LADEN DETERGENT
EJECTION SLOT FOR MUD DEPOSIT AND BROKEN GLASS
CLEANING SWEEPERS REMOVABLE
PRE RINSE JETS
ADJUSTABLE FEET
VARIABLE SPEED DRIVE.
TRAVERSE MOTOR
PUMP MOTOR
WASH PUMP
STRAINER
SLUDGE COCK FOR DRAINING
TRAVELLING DETERGENT SOAK HEATED BY STEAM COIL TO 145°F THERMOSTATIC CONTROLLED

By courtesy of Auto-Dairy Engineers, Ltd.

FIG. 63. "A.D.E. Soakwasher" bottle-washing machine.

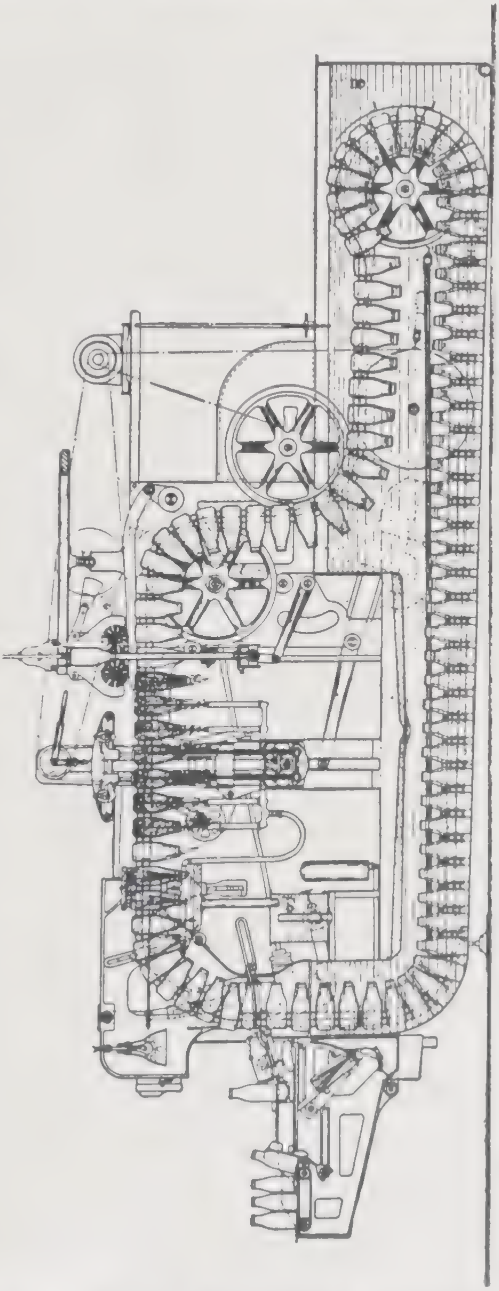


By courtesy of Dawson Bros., Ltd.

FIG. 64. "Dawson" super-hydro bottle washer and steriliser.

The "*Gem*" *Straight-through* washer is designed for the efficient treatment of large numbers of bottles. It is strongly constructed and will give the operator long, efficient and carefree service. Satisfactory temperature controls are provided at all essential points.

As already indicated, the *brush-type washer* is regaining popularity and is now employed in many large dairies. Bottles receive a pre-rinse which prevents contamination of detergent tanks and tempers the containers to withstand high temperatures without fear of breakage. Following pre-rinsing they pass to soaker tanks filled with detergent, the strength of which is usually maintained by means of a drip-feed from above. Following this treatment, the bottles are subjected to thorough external brushing, water being continually flushed through the brushes, after which they are rinsed and then brushed internally. Several rinsings with water at varying temperatures follow and finally the bottles are automatically delivered to the conveyor.



By courtesy of Meyer-Dumore, Ltd.

FIG. 65. "Dumore Junior" bottle washer.

The "*Dumore Junior*" washer makes use of brushes, the bottles receiving a preliminary rinse, followed by a pressure rinse and internal and external brushing. They are then soaked in 3 per cent. caustic solution at 170° F., afterwards receiving final rinsings of warm and cold waters. The rinsing tubes are serrated to remove foreign bodies both before and after brushing. As the bottles are soaked in detergent and hot sprayed, a large savin in detergent is claimed together with a continuous output of pe fectly cleansed bottles. A section of the apparatus is shown i Fig. 65. The "*Miller*" *Hydro* can be obtained using eithe brushes or sprays and capable of handling up to 10,000 bottles pe hour. Both types are entirely automatic in action. The brush type machine gives the bottles a pre-rinse followed by two alte nate pressure washings and brushings. The containers are the sterilised, after which they are tempered to mains wate temperature. The spray type machine gives five tempera ture changes during washing, finishing with steam, but cold bottle can be delivered to the conveyor if desire Both types possess self-cleansing jets and efficient filtratio systems.

All washing machines require to be provided with efficien recorders showing the temperatures in the various solution an hot water tanks, while the thermostatic control of such tempera tures should be considered essential. In addition, adequat lighting is essential at loading and unloading points so that th bottles may be properly inspected for dirt and other materia which may be adhering to their exterior or interior surface before filling takes place.

As will be readily understood, there are various process employed, differing considerably in times of treatment an methods of application. The most favourable factor and the on which is probably the most frequent cause of contamination an lack of success lies in the manner in which the machines a usually employed. The factors chiefly subject to variation a the time during which the bottle is actually undergoing treatme and the temperatures of the various washing solutions and, some machines, the temperature of the final rinsing solutio The detergent employed and the maintenance of its percenta strength, the period during which the solution is in use and th methods used to maintain its strength may vary considerabl The method employed in determining the strength of the soluti and the ease with which this may be carried out must not overlooked. The bacteriological purity of the final rinsing wat in machines designed to supply cold bottles is particular important. The apparatus should be constructed so that pipe lines, water ways, spraying jets and brushes are easi accessible for cleansing purposes, while all sections of the plant should be isolated from each other.

It is necessary to emphasise again that the most general fault in practice is the employment of a weak detergent solution. On the score of economy, too small amounts of detergent are employed in making up the solution, this being indeed false economy, while on many occasions, even if the solution is sufficiently concentrated at the commencement of treatment, no steps are afterwards taken to maintain its original strength. Bottles leaving the solution compartments invariably carry away some small amount of detergent, while leakages and splashing cause additional loss of strength. To prevent losses of detergent in this manner, it is important that adequate drainage periods should be provided. Some machines fail to maintain the detergent solution at a sufficiently high temperature, while operators may be careless in this matter, despite the provision of temperature recorders. To prevent delays bottles are often allowed to pass through the machines before the washing solutions and rinsing waters have attained the correct working temperatures. Operators of bottle-washing machines should be impressed with the necessity for following a strict working routine in order to ensure that every bottle treated may be as nearly sterile as is possible.

Two further points require to be considered. Water jets may frequently become blocked by scale, and, as mentioned previously, it is advisable to install a water-softening plant, unless soft water is already available. The provision of such apparatus ensures economy in detergent. The second point to note is the distance which cleansed and sterile bottles are required to travel to the filling machines. When it is considered that containers to be filled travel with their mouths upwards, and when it is realised how easily they may become re-contaminated, it will be seen that a lengthy travel, usually due to faulty planning, must be avoided at all costs. If this is unavoidable, the conveyors should be covered in order to protect the receptacles.

The frequent examination of bottles as delivered from the apparatus is essential, but they should always be dry before such an inspection is made. The efficiency of the process may be proved by pouring some warm, distilled water into the container to be tested, followed by a few drops of phenolphthalein. The bottle should be well shaken and if the liquid turns pink, alkali is present, and this is an indication that it has not been properly rinsed. Bottles should also be submitted to bacteriological examination at frequent intervals. The method of testing is set out on p. 268.

Certain new methods of bottle cleansing are now the subject of experiment. Bottles, after washing, are being subjected to dry heat sterilisation, while ultra-violet rays have been employed for sterilising purposes. Such methods must not, however, take the place of efficient washing, nor can any laxity in the design of bottle-washing appliances be countenanced.

CRATE WASHING. Empty bottles are invariably delivered to the dairy in crates and, after they have been removed and placed in the washing machine, these crates require attention. If large numbers require to be dealt with, they are passed through a crate-washing machine, which consists of a simple tunnel through which they travel on a chain conveyor. Washing and scraping operations are carried out, caustic-soda solution from high pressure jets, to which they are subjected as they pass through the apparatus, being used for this purpose. They are finally washed with clean cold water before leaving the tunnel. The clean crates are conveyed to a table in close proximity to the conveyors which carry the filled and capped bottles. These machines are usually found only in large dairies which use large numbers of crates, as in small premises they are generally washed by hand. Where large numbers are required to be dealt with, mechanical means of washing should always be provided as this ensures that the crates are a credit to their owner instead of, as is so often the case, being dirt traps and fly collectors.

CHURN WASHING. It will be appreciated that milk churns are extremely difficult to cleanse and sterilise in an efficient manner, containing as they do slime, milk residues and surface film. The problem is rendered much harder by the shape of the receptacle, by its internal condition and by the fact that an interval must of necessity elapse between sterilisation and its further use for the conveyance of milk. In addition, the lids of the containers require treatment, and this point should not be overlooked.

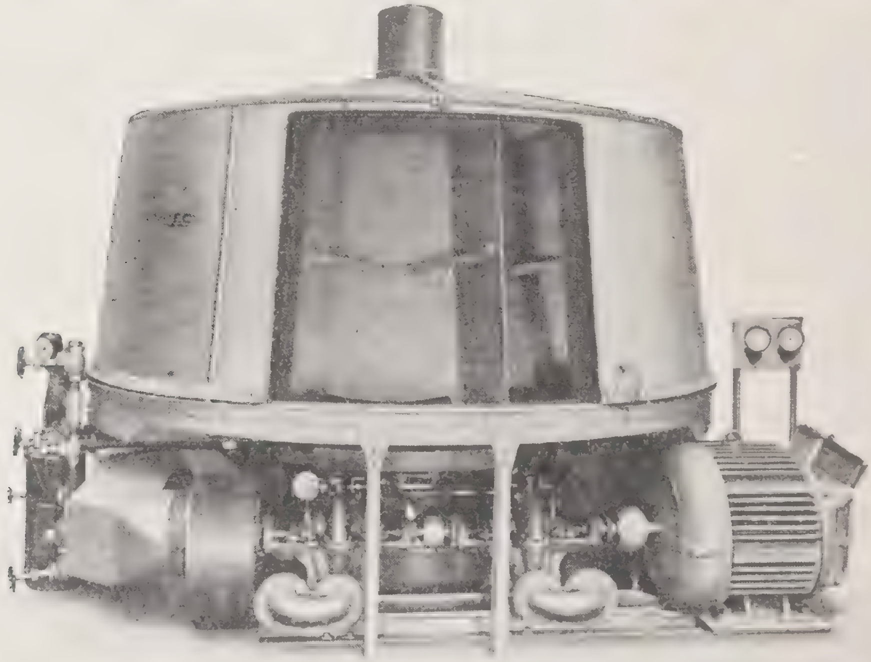
Churns received at small dairies are usually washed and sterilised by hand. They should be rinsed with cold water, following which their internal and external surfaces should be well brushed with hot detergent solution. They should again be rinsed with hot water and finally sterilised by means of steam, either by employing a steam chest or by inverting each can over a steaming block. When this treatment is completed, they should be allowed to dry, after which they may be closed down. The lids should be separately treated by hand.

This process is often carried out in a far from satisfactory manner, and the small distributor will obtain valuable assistance from the employment of hypochlorite solutions. A concentration of 300 p.p.m. should be used for this purpose and this will necessitate the addition of two pints of an approved hypochlorite to 100 gallons of water. In many creameries, automatic churn washers have still not been installed, and hand washing with jet sterilisation is still practised. Generally in such cases it will be found that during the peak period both washing and steaming times are entirely inadequate. Mattick has stated that each churn requires to remain over the steam jet for at least 3 minutes, a period which is rarely attained where this method is employed.

The procedure at large dairies and creameries where hundreds of churns have to be washed and sterilised daily must obviously be carried out in a somewhat different and more speedy manner, hand treatment being both laborious and uneconomical. Under such conditions, the washing and sterilisation of churns is carried out in a more or less automatic manner, two types of mechanical washers being employed for the purpose. Preferably, these machines should be sited near to the receiving platform for convenience in handling the empty containers.

In choosing a churn washer several points require to be taken into consideration. The strength of the detergent employed and its automatic measurement and maintenance at full strength are extremely important, as also are the cleanliness and working efficiency of the entire apparatus. Proper provision for the drainage of milky dregs before churns are loaded into the machine should be regarded as essential. This will prevent fouling of the detergent compartments and cut down milk losses, and it should be impossible for any detergent solution to be carried forward while the apparatus is in motion. In addition, the final rinsing water should be protected against contamination. Every machine should provide for the final drying of the containers with hot air. When at work, all steam and vapour should be removed from the vicinity of the apparatus and temperature controls, pressure gauges and control valves should be preferably centred at some suitable point. The apparatus should be easily accessible for cleansing and inspection. Further, as churns have tinned surfaces, the detergent employed should not possess the usual corrosive action of alkalies on such material.

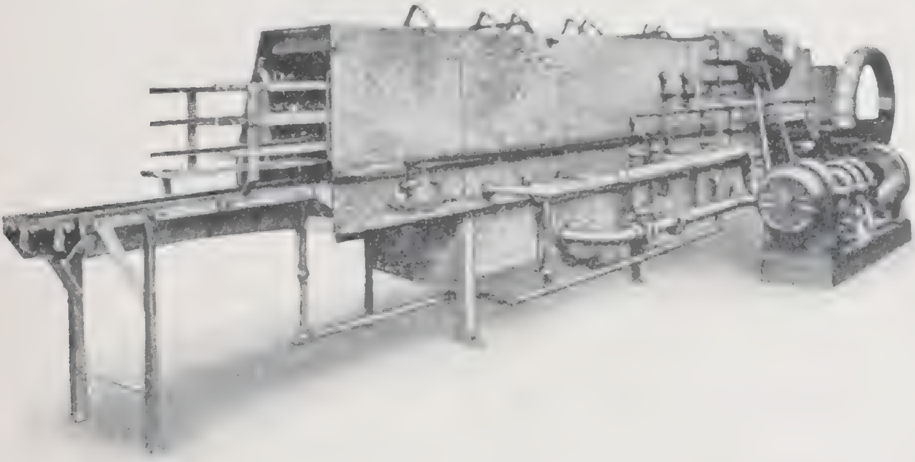
The *rotary machine* is the simpler of the two types of washer employed, being operated by one person who places dirty churns and lids into the machine and removes them when cleansed. The apparatus consists of a tank divided into sections. Mounted above this is a slowly rotating container also divided into compartments and surrounded by a closed cover which is provided with an outlet into the open air. The churns are placed in the separate compartments of the container as they revolve, along with their lids, and travel back to the loading point. They are subjected first to a cold water rinse, three applications of hot 1 per cent. soda-ash detergent solution at temperatures between 140° to 160° F. and hot water rinses at 180° F. and 200° F.



By courtesy of the U.D. Engineering Co., Ltd.

FIG. 66. "Udec" rotary can washer (capacity 6 cans per minute).

respectively. They are finally sterilised with steam, after which a powerful air current at a temperature of 230° F. is employed to provide final sterilisation and to dry the container. When treatment is completed the churn appears at the opening in the cover and is removed. Another container is placed in the vacant compartment, continuous processing being obtained in this manner. The lids may, if desired, be treated separately, but in some washing machines they are sprayed by means of the horizontal jets, which also deal with the external surfaces of the churns. The sprays of water and detergent are forced into the containers by means of a centrifugal pump or pumps. Hot air drying is frequently resorted to in order that they may leave the apparatus in dry condition. This allows them to be immediately closed down. An example of this type of apparatus is the " *Udec* " *Rotary Washer* shown in Fig. 66. This machine can deal with up to six churns and lids of from 10 to 17 gallons capacity per minute by the stages outlined above. The three-churn-per-minute apparatus gives five stages of treatment, only one detergent wash and one hot rinse being provided.



By courtesy of the U.D. Engineering Co., Ltd.

Fig. 67. " Udec " straight-through can washer (capacity 10 cans per minute).

In the larger capacity machines, the churns travel through an apparatus of the *straight line type*, being fed into one end of the machine and leaving at the other in an almost sterile condition. They are subjected to a pre-rinse with cold water, followed by three washings with hot detergent solution. A hot water pressure rinse and a sterile rinse are then given. This is followed by steam sterilisation, the churns being finally dried with superheated air at a temperature of 230° F. This type of plant can deal with a large number of containers per hour and is illustrated in Fig. 67.

It is a statutory requirement that all churns should be washed and sterilised before being returned to the producer, and mechanical washers must be operated properly and receive adequate attention if they are to accomplish cleansing operations in an efficient manner. Temperature in all sections of the plant is again of the utmost importance and temperature recorders should be fitted and frequently inspected to see that correct levels are maintained. Operators are often averse to running the machine at the desired temperatures as churns are then uncomfortably hot to handle. Unless the discharged containers are extremely hot on leaving the apparatus consistently good results cannot be guaranteed. Detergent strength also requires constant attention. When work is completed for the day, all water and detergent tanks should be emptied and the internal surfaces of the washer and its tanks thoroughly cleansed. Jets should be inspected and scaled if necessary and all mechanical parts receive attention. Lack of care in maintenance results in inefficient churn cleansing, unclean containers causing contamination of milk at the farm, however clean such milk may be when produced. The present state of churns reaching producers' premises has repeatedly caused complaints, and greater attention should be paid to this problem by those responsible. The constant stress on improved production methods must remain ineffective if churns are returned to the farm in a damp, foul-smelling condition, or containing milk residues and visibly unclean.

CHAPTER XI

CLEANSING OPERATIONS

MILK, although an important food, is highly perishable, and it must be handled in clean, sterile equipment which will prevent all possible chance of contamination. A good product is always associated with the satisfactory cleansing and sterilisation of the apparatus, and distributors who pay little attention to the appearance or cleanliness of their plants and staff are usually careless about other matters which are also of great importance. The maintenance and cleanliness of the plant should be the responsibility either of the manager or the laboratory technician. It should be inspected by the person appointed once weekly and an inspection sheet prepared, showing any items which are unsatisfactory marked in red. Daily inspections should be carried out by the dairy foreman who should also prepare a daily report. Careful attention to cleanliness and maintenance will be amply repaid.

Statutory Regulations require all milk vessels and equipment to be kept in a state of thorough cleanliness at all times by being washed immediately after use. cleansed. and scalded with boiling water or steam. Hypochlorite solutions may be employed for sterilisation purposes, but all traces of such solutions must be removed before the treated parts once more come into contact with milk. It is particularly important that the pasteurising plant and its subsidiary apparatus should be efficiently cleansed and sterilised at the end of each day's operations. Unless this process is carried out efficiently, the bacterial content of the final product will be so excessive as to render processing a waste of time, energy and expense. Post-pasteurisation infection is extremely common in many dairies, and for this reason cleansing and sterilisation should never be dismissed as a waste of time and material. Such infection normally occurs in pipe-lines delivering cold milk to the bottle-filling apparatus as well as in the filling heads of that machine. and these points require the strictest care.

It is imperative that plant cleansing should follow strict routine, the work being performed under proper supervision. It cannot be too often stressed that lack of care in these operations results in an unsatisfactory product ; indeed, many of the disappointing results obtained from well-designed apparatus are actually due to such carelessness. Improperly cleansed equipment will result in the presence of large numbers of bacteria, while any milk solids allowed to adhere to the internal surfaces of the plant act as culture media for such organisms. Given food and a moist atmosphere they will reproduce at a rapid rate. Further, if not quickly removed, milk solids accumulate and become hardened by frequent heating, forming what is known as "milk-stone," a material which is extremely difficult to remove without damage to the surfaces to which it is attached. Owing to the action of lactic acid in conjunction with moisture, these solids exert a damaging effect upon certain kinds of metal surfaces.

The term "*milk-stone*" is employed to denote the precipitate which adheres to equipment coming into contact with hot milk. In dealing with the cleansing of pasteurisation plant, this substance requires special consideration. Once it has formed and has been allowed to accumulate, it is extremely difficult to remove. Milk-stone is composed of the milk fat, protein and mineral matter, in addition to which it is also possible that the precipitate which forms in the process of softening hard water with detergent also becomes embedded in the mixture. After processing has been completed, a film of milk usually remains on the inside surfaces of the apparatus. This precipitate is sticky or gummy when first deposited and can be removed quite simply by the application of detergent solution at medium temperatures. Any high temperature is likely to increase the adhesiveness of the material and cause increasing difficulty with its removal. With low-temperature pasteurisation, the employment of a heating medium at a temperature not exceeding 148° to 150° F. assists in preventing milk-stone formation. Further, it is important that the system should be cooled with cold water immediately after processing is completed. An alkaline detergent should be used which, when softening hard water, does not produce a granular precipitate which settles quickly or has any tendency to adhere to the equipment. Such detergent should rinse easily from the surfaces of the apparatus. The temperature of the washing solution should never be lower than 130° F., while after this process is completed the equipment should be immediately rinsed with cool water.

Dried-on milk-stone may be removed easily with a ½ per cent. tartaric-acid solution employed in conjunction with friction.

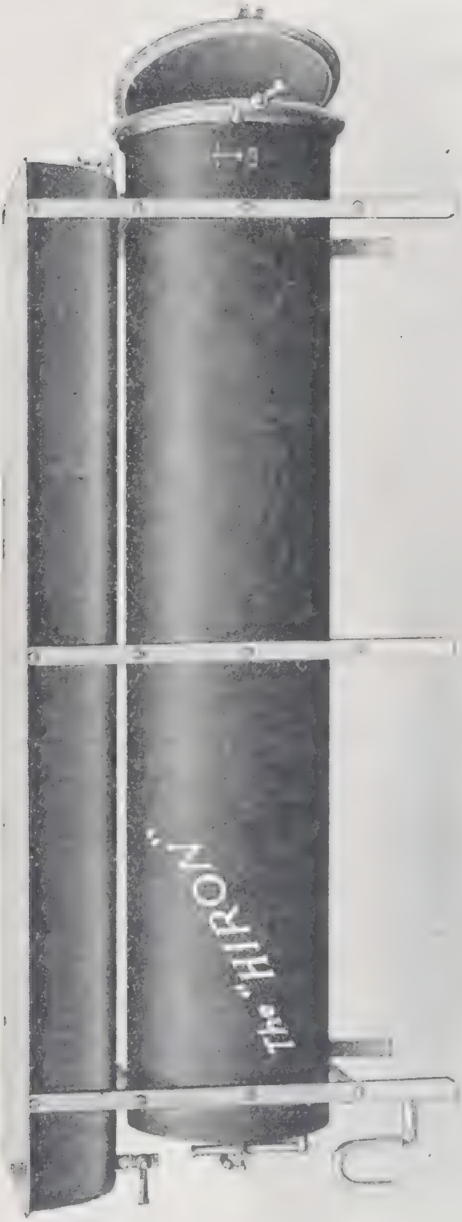
The cleansing of dairy equipment must always be regarded as a major operation and not as a necessary evil or as a non-productive part of processing, otherwise the apparatus may be quickly ruined while the product will be rendered unsatisfactory if improper cleansing methods are adopted. The majority of cases of reduced keeping quality in processed milk are due to improperly sterilised plant, and the cleansing of the apparatus is just as important as the methods of processing which have preceded it. The temperature differences between the heating medium and milk together with failure to speedily cool the equipment and wash it thoroughly after use, causes milk solids to become burnt on the internal surfaces of the apparatus. Immediate attention as regards the cooling and washing of heated apparatus will considerably assist subsequent cleansing operations. Another important factor must also be considered. Mineral salts are bound together by milk proteins and fat and this milk fat must be emulsified and the proteins softened and removed so that the whole may be carried away by the detergent solution.

Washing operations are necessary to remove all traces of milk remaining after processing has been completed in order to leave a clean surface suitable for, and one which will facilitate, subsequent sterilisation. Apparatus should be thoroughly rinsed after washing is ended to prevent the burning-on of deposits loosened by detergent; this treatment will prevent any corrosion which might result from continued exposure of metal to detergent solutions. In some dairies it is the practice to wash and thoroughly cleanse daily only those parts of the plant which are easily accessible, while enclosed apparatus, such as heat-exchangers, homogenisers, pasteurisers and fillers are washed through with various solutions, together with a de-scaling fluid circulated at infrequent intervals, dismantling taking place as circumstances permit. This is an exceedingly short-sighted policy which must be the cause of much re-contamination of the final product, but it is perhaps understandable when it is remembered that cleansing operations require to be carried out on every day during the year.

Washing alone is not sufficient, sterilisation being necessary and extremely important. For correct sterilisation, some form of heat is essential, either steam, hot water, hot air or hypochlorite solutions being employed. The two main factors which decide whether sterilisation is satisfactory are the temperature to which the surfaces are subjected and the time such temperature is maintained. All pathogenic organisms and most non-pathogens are destroyed if subjected to a temperature of 180° F. for a suitable period. Steam temperature is higher than that normally required to kill most bacteria, but this does not mean that the external surfaces of a cooler, the lower tubes of which are filled with chilled water or brine, will be rendered sterile by the application of steam. Sterilisation of surface coolers is easily effected if the cooling agent is withdrawn and the steam passed through the internal waterways of the apparatus. The temperature attained in this manner will destroy organisms present on the external surfaces owing to the heat which the metal attains. Hot water is more efficient than steam when open equipment requires to be sterilised, always provided that a temperature of not less than 180° F. is maintained for at least 20 minutes. Steam is, without doubt, most suitable for use with closed vessels, and this point must be remembered when cleansing operations are considered. Sterilisation is the final treatment before the following day's run takes place, and for this reason any handling of the plant after this process has been completed should be entirely avoided.

As already mentioned, cleansing operations must follow strict routine, and while it is possible to deal with a small plant as one unit, large plants require to be divided up into separate sections, each of which needs individual treatment. Immediately processing has ended, cold water should be passed through the plant in a similar manner to that of milk. The plant should then be flushed with warm water and the bolts of the heat-exchanger and other joints should be slacked off slightly in order that water and subsequently detergent solution can leak out and clean every portion of the surfaces. A similar treatment with hot water at a temperature of not less than 130° F., to which a reliable detergent at the approximate rate of 1 lb. of detergent for every 20 gallons of water has been added, should follow. The volume of water passed through should be sufficient to ensure that all liquid milk is washed out of the various portions of the apparatus and pipe-lines. The interior of holders and surfaces of any open coolers should be well scrubbed during the period water or detergent solution is passing through.

All portions of the plant which cannot be thoroughly cleansed without dismantling should then receive attention. When this operation is completed they should be well scrubbed with detergent solution, followed by clean hot water. All sections of *pipelines*, together with other small portions of the apparatus, should



By courtesy of Hiron and Rempler, Ltd.

FIG. 68. "Hiron" pipe-cleaning and sterilising outfit.

be steamed for at least 10 minutes and, after steaming, either stored in a suitable place and protected from contamination, or reassembled.

The apparatus illustrated in Fig. 68, is designed for the cleansing and sterilisation of sections of pipe-line. These sections are washed in the tank which forms the upper portion of the apparatus; after this process has been completed, they are placed in the drum forming the lower portion of the outfit, and are sterilised with steam. As many washing tanks are too small to ensure that pipe-line sections are fully immersed during the process, while sterilisation with steam is sometimes difficult, this apparatus will be found extremely useful.

Once again it is necessary to emphasise the necessity for providing soft water for cleansing operations, some form of water-softening plant being essential to precipitate any calcium and magnesium salts which the liquid may contain. When these chemicals are present, they exhibit a tendency to combine with fats and form a gummy deposit which is extremely difficult to remove.

Filters, *heat-exchangers*, *holders*, *receiving vats* and *tipping tanks* should be well scrubbed with hot water at 160° F. containing detergent and should be finally rinsed with clean hot water, care being taken to remove all "milk-stone" during these operations. *Coolers*, or that portion of the heat-exchanger responsible for cooling milk should receive particular attention; any lack of sterility here will result in the re-contamination of the treated product. No cooling system has been satisfactorily cleansed unless sterile water can be passed through it without re-contamination.

The general principles outlined apply in every case; the application of these principles varies according to the type of apparatus dealt with, the types of surfaces to be cleansed and the materials used in construction. It is now necessary to consider how these principles can be successfully applied to various parts of the plant but, before doing so, the detergents employed require consideration.

Detergents, whatever their type, should fulfil certain conditions. First and foremost, they should be safe and easy to handle, possess the ability to form a good wetting contact with the surface to be treated and they should also be able to dissolve the milk proteins, forming an emulsion with the fat in order that such impurities may be easily removed. Detergents should possess the ability to break up dirt particles so that micro-organisms are removed, should possess sterilising properties, should not cause troublesome foaming, and should soften the washing water so that there should be no gummy deposits or lime formation. They should exert no harmful effect upon the surfaces with which they come into contact, being absolutely non-corrosive when highly concentrated and under conditions of high temperature, while they should possess free-rinsing properties. In addition, they should be compounded so that they possess a reserve of cleansing strength with high causticity which should not be dissipated too quickly during use and should be maintained in storage. Their quality is important, considerable damage to plant occurring through the employment of corrosive cleaning powders and harsh abrasives. It must be remembered also that corrosion of equipment is a major factor in the development of metallic flavours in milk. The most common detergent base is caustic soda, and this is supplemented with other chemicals such as sodium carbonate, trisodium phosphate, sodium metaphosphate and sodium metasilicate, these latter being chosen according to the hardness of the water. The two latter chemicals are useful for removing stubborn deposits and for imparting a shine to the bottles. The amount of detergent which should be employed depends upon its strength and condition, the period to which deposits on plant surfaces are exposed to its action and the temperature of the solution. Stubborn deposits will always require stronger solutions applied at higher temperatures for longer periods. Generally it may be stated that a strong solution at a high temperature will clean best but may exert a corrosive effect on metal surfaces unless, of course, a non-corrosive cleaner is employed. The sterilising efficiency of a detergent depends upon its caustic alkalinity and temperature, and Mattick and Hoy have recommended temperatures above 130° F. and a titratable value equivalent to not less than 0·5 per cent. caustic soda using phenolphthalein as an indicator. The solution should be controlled by regular titration and further quantities of detergent should be added, as required, to maintain its alkalinity.

Detergents can be obtained either in powder or liquid form, and as the water supply usually varies from district to district, the manufacturer should always be consulted as to the type required, following an analysis of the water available. Test outfits can be obtained which may be used for checking the strength of the detergent, and these should be regularly employed for this purpose. A measure of known capacity should be provided so that the solution may be of consistent strength. Certain solutions now employed may remove bacteria without materially affecting the spores, and generally it may be stated that detergents are not good germicides as they do not destroy micro-organisms. On the other hand they serve a valuable purpose as, by removing organic matter from the interior surfaces of apparatus, they make life untenable for such organisms as may be present. Unless the detergent is of the highest quality, large numbers of these organisms may escape removal during the washing process and for this reason not only is a really good detergent essential, but final sterilisation should never be omitted. Detergents should always be used which have been specifically designed for plant cleaning. One which loosens the milk film sufficiently for it to be washed away is just as satisfactory and efficient as a strong alkali which will entirely dissolve the film but which exerts such a deleterious effect upon the metals with which it comes into contact.

Tipping tanks require to be hosed, first with cold and then with hot water. The outlet valve should be closed and detergent solution (0·25 per cent. soda ash in water at a temperature above 130° F.) poured into the apparatus ; then, by employing a suitable bristle or wire brush, the internal surfaces should be thoroughly scrubbed with the solution. The liquid is drained from the outlet, the washed surfaces being brushed with clean warm water and finally rinsed with warm water from a hose. The internal surfaces should finally be sterilised with either boiling water at 180° F. for 20 to 30 minutes or by steam directed by means of a jet. When treatment is completed, the tanks should be covered to afford protection against dust and other contaminating influences. The external surfaces require to be treated similarly to remove any milk splashes or dust and to maintain a cleanly appearance. Strainers and filters must be thoroughly cleansed and any fabric filtering media should be destroyed.

Modern *pumps* are easily dismantled for cleansing. Removable parts should be washed, brushed, given a further washing and brushing with detergent solution and finally treated with hot water at the requisite temperature. The outer irremovable portions should be similarly treated both internally and externally. After a final rinsing, they should be re-assembled along with the pipe-lines and sterilised by pumping boiling water or steam through them. It should be remembered that steam does not pass very easily through certain types of pump and for this reason water at a temperature of not less than 180° F. will have to be employed.

Pipe-lines should be flushed with warm water and afterwards dismantled into convenient lengths for further treatment. These sections should be submerged in troughs of hot detergent solution, of the type mentioned on p. 218, which can handle several sections at one time. Their internal surfaces should be well brushed, a rotary wire brush possessing a high-speed flexible drive being suitable for this process, and care must be taken to ensure that the brushes employed pass completely through the pipes. The sections should then receive a further washing with hot water, or be re-assembled and such water pumped through them for rinsing purposes. The whole length of pipe-line, when re-assembled, should be sterilised by passing through water at a temperature of 180° F., or steam for 10 to 15 minutes. Steam employed for this purpose should be as dry as possible, as any moisture remaining in pipe-lines will assist in the development of bacterial spores. The sections may be sterilised with steam before re-assembly if desired. Hypochlorite solution at a strength of 250 parts per million and at a temperature of 170° F. is recommended as a sterilising agent in lieu of either hot water or steam as, when employed, bacterial growth does not occur in the moist tubes. If this chemical is not used, it is advisable for pipe-lines to be re-sterilised some time before processing is commenced in order to destroy any bacterial growth which may have taken place. The pipes of the cooling section must, however, be allowed to regain their normal temperature before milk is again passed through. Stainless metal pipe-lines may be occasionally immersed in 2½ per cent. caustic-soda solution at 180° F. for 20 minutes. This treatment will completely loosen any milk-stone which may have formed, which can subsequently be removed by means of an ordinary fibre brush.

"*Batch*" *holders* should be treated in a manner similar to that described for tipping tanks, but *rail tanks, storage tanks* and *larg holding compartments* require special treatment. A large containe renders it necessary for the operator to enter the interior. Fo this reason, rubber boots must be worn in order that the interna surfaces are not scratched or damaged in any way. Rubber boot are common wear in large processing plants and are easy to clean but it should be pointed out here that boots employed for thes particular cleansing operations should be special pairs, whic are not normally used during processing. They should be fitte by the operator immediately prior to entering the tank. Larg tanks receive similar treatment to tipping tanks and " Batch " holders. Long-handled brushes are employed to reach thos surfaces not easily accessible to the ordinary type of scrubber Internal surfaces should receive a good scrubbing with warm water to remove any adhering milk solids, detergent solutio being used for further scrubbing, following which all surface should be thoroughly washed down with warm water from hose. Each tank should receive a further wash with warm wate after the operator has left. Steam should be admitted to sterilis the internal surfaces and the openings closed until the tanks ar required for further use. The outside surfaces of tanks an holders should never be overlooked during cleansing operations Where mechanical agitation is provided, holders and tanks ar more difficult to deal with. Care must be taken to ensure th removal of any dried-on milk solids from the agitators befor washing with detergent solution is commenced. *Glass-enamelle vats and holders* require careful treatment. No alkalin detergents can be employed as these will attack the enamelle coating and cause minute scratches on its surface. Any carbonat or abrasive has the same effect and is quite as efficient as a alkaline liquid provided the surfaces to be treated are thoroughl brushed. If care is not exercised in cleansing operations, " milk stone " forms and it may not be possible to remove this materia without damaging these linings. Improper cleansing usuall results in their entire destruction.

Hypochlorite solution can be used for the sterilisation of th interior surfaces of large tanks as the use of steam, particularl in the case of insulated containers, raises the temperature of th interior surfaces sufficient to prevent adequate cooling before th milk again enters. The most practicable method is to appl such solutions by means of a high-pressure spray, and the liquid should be in contact with the surface for at least one minute for each 20 square feet to be treated. One half-gallon of solution is required for the treatment of this area.

Plate heaters and coolers of the regenerative type should be washed with warm water to remove milk still adhering to the plates. This should be followed by the circulation, for 30 minutes, of warm detergent solution at a temperature of not less than 160° F. through the apparatus. Only a small volume of detergent is necessary as this may be re-circularised from the discharge end, provided the temperature and strength of the solution is maintained during the entire period. The solution employed should be composed of 4 lbs. of detergent powder mixed with 20 gallons of water. The plates should be separated singly, both sides of each plate being brushed with detergent solution. Care must be taken to ensure that the gaskets which seal the plates are not injured during this process. After the plates have been separated and cleansed, they should be washed thoroughly with hot water from a hose, being well brushed during the entire period. The apparatus should then be closed and boiling water or dry steam passed through for 15 to 20 minutes. It should be remembered that the excessive application of steam for this purpose is liable to damage the rubber gaskets which first become swollen, then distorted, and eventually require to be renewed. This method of treatment is, of course, applicable to the plate apparatus employed for short-time processing. While steam is passing through, the plates should be well slacked off or a broken casting may ensue. Hypochlorite solutions (250 p.p.m.) can also be employed for sterilisation purposes.

Large surface coolers should be rinsed with warm water, the corrugated surfaces being vigorously brushed. Warm water from the holding compartments can be employed for this purpose, the treatment being followed by the application of warm detergent solution, 0·25 per cent. soda ash in water at a temperature of not less than 130° F. being used. Vigorous brushing is once more essential to remove all traces of milk solids and fat, the cooler being subsequently rinsed with warm water. Finally, hot water at a temperature of at least 180° F. should be discharged over the cooler surface from the distributor trough for a sufficient length of time, approximately 10 to 15 minutes, to ensure that the metal is thoroughly heated and sterilised. A similar washing treatment should be applied to this trough and also to the collecting trough at the base of the apparatus. *Cabinet coolers* are similarly dealt with, each section receiving separate treatment. The metal covers provided should not be overlooked, each surface requiring to be thoroughly cleansed. Finally, steam should be passed through the cooler compartment for 15 to 20 minutes, underneath the covers, the lower ends of which should be opened sufficiently to allow its escape and the tubes to dry. If brine is used as the final cooling medium, this section will be difficult to sterilise thoroughly with steam owing to the presence of cold brine in the tubes. Coolers of this type should be provided with some means of draining away this liquid before cleansing and sterilisation takes place. Alternatively, water at a temperature of 180° F. applied for 10 to 15 minutes, will be found a most efficient sterilising agent for brine-cooled sections.

Tubular milk heaters and coolers should be rinsed by passing warm water through their tubes, this treatment being followed by the application of a suitable detergent solution. The end caps of the tubes should be removed, detergent being applied with a long-handled brush which must be drawn backwards and forwards several times. After the adhering milk film has been loosened, the tubes should be hosed and brushed with clean warm water. The end caps should be rinsed and well brushed, the apparatus closed and steam or hot water passed through for 15 to 20 minutes. This treatment is satisfactory for Stassanisers and for the tubular apparatus employed in the short-time process. Continuous-flow heaters have large tubes which can be readily cleansed by means of a mechanically-operated brush. It must again be emphasised that lack of proper sterilisation in the cooling section of the plant will mean re-contamination of the pasteurised product.

Filters and clarifiers should be cleansed by means of warm water, followed by hot detergent solution, vigorous brushing again being necessary. This treatment is followed by a further application of warm water, the apparatus is closed and sterilisation by means of hot water or steam takes place. All filtering media should be destroyed after each day's run.

Bottle filling machines should be drained of milk and rinsed with warm water. Valves should be removed, rinsed and washed separately in the normal manner. The air escape tubes which extend through the valves should be cleansed by means of the special brush which is usually provided and the receiving bowl rinsed and brushed thoroughly with detergent solution, being afterwards washed with hot water. After washing operations are completed, the valves and rubber components should be placed in the receiving bowl and, with the cover affixed, be steamed for 15 to 20 minutes. The steam pipe should be inserted in the cover aperture, being covered with a clean cloth to prevent the escape of steam from the bowl and in order to maintain a sufficiently high temperature. Care must be taken to guard against the re-contamination of valves and rubber parts when the apparatus is re-assembled. Sterilisation with hypochlorite solution (250 p.p.m.) at this point is also recommended and the apparatus should be finally flushed with chlorinated water which must drain away thoroughly before it is again operated.

Homogenisers should be properly cleansed and sterilised immediately processing is completed, cold water being pumped through the apparatus under pressure, until clear water is discharged. Any removable parts should then be washed and scrubbed separately. This treatment should be followed by hot water rinsing, with final sterilisation by water at 180° F., as steam will cause the rubber parts to perish. The apparatus should be re-assembled and hot water pumped through under pressure. A further hot water wash should be given with sterilisation by hot water as the final treatment. Pumping solutions through the apparatus ensures that all milk residues are forced out of ram chambers, stuffing boxes or glands. The plugs should be removed from the valve chest and this portion of the homogeniser is then accessible for brushing.

Bottle-washing machines require careful attention. Jets should be inspected for chokage and all *débris* and any broken glass removed. Adjustments as to the correct centring of the jets may be necessary while tanks must be emptied and strainers cleansed. Any excessive daily quantity of broken glass should be noted as this may be due to excessive temperature changes between the various sections. In such instances, temperatures should be checked and recorders examined against an instrument of known accuracy.

After all sections of the processing plant have received proper cleansing, the *walls and floors* of the various rooms must not be overlooked. These should receive treatment immediately other duties are finished. Walls and ceilings collect a good deal of dirt and should be washed sufficiently often in order to ensure a good appearance. Dirty windows are extremely unsightly, as well as an obstruction to daylight, and require to be cleansed regularly, while dairy floors, which become dirty through films of milk solids, fat and washing powders forming on their surface, should be scrubbed and cleansed daily. Not only do floors emit foul-smelling odours when not regularly cleansed, but *drains* also should receive constant attention in order to obviate any nuisance in this connection. Dairy wastes are difficult to dispose of and are likely to cause considerable nuisance if not treated in a satisfactory manner.

Sodium hypochlorite solutions may now be legally employed and such solutions are quite efficient if correctly used. Surfaces so treated will remain satisfactory for at least 12 hours, even if the air temperature is in the neighbourhood of 65° F. It must be remembered that they do not possess the penetrative effect of heat, while if care is not taken, the liquid will exert a corrosive effect on the metals with which it comes into contact. The recommended solutions are relatively stable and the manufacturers' statements as to the percentage of available chlorine may be accepted as correct. Under satisfactory storage conditions in a cool, dark place, these solutions should not lose more than 0·5 per cent. of available chlorine each month. The *chlorine wash* is made in water warmed to a temperature of 160° F. or higher and sufficient stock hypochlorite added to give 250 to 300 p.p.m. (per million parts of water). The chlorine concentration should never fall below 150 p.p.m. during use, and this solution is intended for washing, spraying or flushing. One-quarter per cent. soda ash can be added, if desired, to act as detergent. *Chlorinated water* is prepared by adding stock hypochlorite solution to clean water to give 5 to 10 p.p.m. of chlorine, and is used for rinsing vessels after the chlorine wash has been applied. Active chlorine, in the form of hypochlorite solutions will be found extremely useful in dealing with infections of thermophiles in the plant. All parts likely to be affected should be treated with a solution containing from 50 to 100 parts per million of active chlorine. The plant must, of course, be entirely freed from any milk residues before these solutions are applied otherwise their sterilising effect is considerably reduced and traces of hypochlorite should be removed by the use of large quantities of clean or chlorinated water. The employment of these solutions is an emergency measure due to war conditions, and, if such solutions are used for plant sterilisation, the apparatus must be treated with steam or hot water at least once weekly. Where either steam or hot water are regularly available, serious consideration as to the advisability of using these solutions is necessary.

Before the plant re-commences processing after cleansing and sterilisation has taken place, hot water with a temperature of not less than 160° F. at the discharge point, should be passed through the various components. This procedure will wash out the internal surfaces of the apparatus, which in warm weather may have acquired an increase in their bacterial population overnight, and will give the plant a preliminary warming before milk is passed through. Care should be taken to prevent any water being retained in the apparatus following this operation as cases have occurred where small percentages of added water have been found in samples of pasteurised milk as a result of this procedure. By exercising the greatest care in cleansing operations, the bacterial content of the product will be materially decreased and its value considerably improved.

CHAPTER XII

PLANT INSPECTION

Owing to the rapid increase in the sales of pasteurised milk, which consumers should be able to rely upon as a liquid which is entirely safe, it is necessary that processing should be entirely efficient so that its product may never be doubted. There is every reason to believe that pasteurisation, as carried out in many dairies at the present time, is not always satisfactory although, if such treatment is undertaken in an efficient manner, the resultant product will be entirely reliable for consumption. It is lack of efficiency and want of care which causes trouble and provides those arguments which critics are eager to use against the process. Carelessness is not generally wilful and may not always be the fault of the owner of the plant or his operatives, although this undoubtedly is so in a number of cases. In many instances, the apparatus used is not satisfactory, attempts at combining different types at various times having led to serious difficulties in milk treatment. Some of the most serious of these occur through the re-contamination of milk after it has received adequate processing, a point which is not sufficiently realised by all concerned. In addition, there is, on the part of those responsible for both operation *and* inspection, a lack of experience and understanding of the principles of plant operation which is most noticeable.

While considerable attention has been paid to the process of pasteurisation from the point of view of milk safety and also from a nutritional standpoint, the technical aspect of the process has failed to receive the attention which it deserves. Supervising officers have to exercise certain functions with regard to the pasteurisation of milk. For this reason it is essential that they should possess a sound, practical knowledge of the technical aspect of the process and should be able to discuss the operation of any plant on equal terms with its owner.

Not only is there an existing lack of knowledge among such officials, but, what is perhaps less understandable, there is often a serious failure to appreciate properly the principles involved in processing on the part of many of these persons owning and maintaining such plants. This lack of knowledge is most remarkable when one considers the number of instructional courses, admittedly still far from adequate, now held in technical colleges throughout the country which deal with the technique of milk processing. This number, while it is increasing, should be extended, and no owner or operative ought to be allowed to process milk without holding some certificate of competency issued by examination at the conclusion of a course of this type. Indeed, before a licence to operate any plant is granted, it should be conditional upon the operator and his foreman holding certificates to prove that they are qualified to supervise the method of processing employed. The large firms are fully alive to their responsibilities and are almost invariably progressive. Among the smaller distributors, however, there is not always sufficient understanding of the essentials of efficient treatment, and it is to the controlling official that such persons most often look for guidance.

The Report of the Cattle Diseases Committee of the Economic Advisory Council, published in 1934, recommended that only officially-approved plants should be employed for pasteurisation purposes and that all plants, on erection, should be tested to ensure that they complied with the approved design. This should be a statutory requirement as should the certification by the licensing authority of the plant and its temperature-controlling instruments, and no alterations or additions should be allowed without re-certification. It has been repeatedly emphasised that frequent inspections under working conditions are necessary and that inspectors should apply certain prescribed tests, recording the results of such inspections and tests at each visit. The inspector should insist upon the strict routine treatment of milk and upon the cleanliness of the plant being strictly observed while the closest co-operation should exist between the distributor and the inspecting official on all points, in order to ensure that the customer obtains a satisfactory article. It should be pointed out that, while the inspector might be expected to criticise, such criticism should be as constructive as possible.

It is a matter for regret that all pasteurisation is not efficient, especially the so-called "commercial pasteurisation," which is usually employed in order to improve the keeping quality of milk. There is, indeed, far too much processing of this type now carried on in this country and the licensing of heat-treatment plants, outside the control of the recognised authority, is not likely to assist in improving such conditions. Stricter control by qualified persons is essential if processing is to be really efficient and worthy of the confidence of the public. Efficient treatment will destroy the organisms of tuberculosis and other diseases, but with inefficient processing this aim will not be achieved, owing to fluctuations in temperature, mechanical defects in the plant and inadequate holding periods at temperatures lower than are essential, with a view to preserving the cream-line. Ministry of Health officials, following inspection, have discovered that many plants producing so-called "pasteurised" milk are inefficient, and so long ago as 1931, Sir George Newman, in his Report, mentioned this fact. The principal defects found were unsuitable premises with inadequate protection from external dust, apparatus of unsatisfactory design, insufficient insulation of the holding compartments, and the exposure of milk to contaminated air after treatment. In some cases, temperature control was inefficient, and, in one case, where milk was produced under licence, no thermometer of any kind was fitted at any point in the plant.

The control of pasteurisation may be divided into two distinct sections, each of which is complementary to the other. These are inspection of the plant and methods and laboratory control (see Chapter XIII) which is so essential in order to determine efficiency.

Inspection of Plant and Methods. No two persons visiting a processing plant would carry out an inspection in a similar manner, and, in the past, lack of uniformity in this direction has been very noticeable and has produced obvious results. It cannot be too often emphasised that uniformity in this matter is extremely important, it being essential to make certain that no portion of the plant or the methods employed are overlooked when an inspection is made. The essentials of adequate inspection may be more conveniently discussed under separate headings.

(*a*) PREMISES. It is important that the plant operator should be well versed in the various regulations affecting processing as well as in the methods of milk supply. The inspector should insist that strict attention to cleanliness is observed at every stage of treatment. The person in charge should be fully conversant with routine dairy management and should exercise his constant personal supervision over plant and methods employed. The routine of processing must be orderly and methodical.

Premises should present a well-kept, cleanly appearance, free from dust, dirt and flies, while any corners and surroundings of the apparatus should receive a thorough inspection as regards visible dirt and filth. The inspecting official ought immediately to obtain an impression that hygiene is of paramount importance. The utmost tidiness should prevail in every part of the plant and cleanliness, together with orderly system, should be obvious in every department. Neglect in keeping inaccessible or out of the way corners clean is one of the great failings of plant operators. There should be no dripping of condensed moisture from damp ceilings, no leaking overhead pipes or leakage of milk from defective pipe-line connections, while the premises should be free from effluvia. The floors, walls and ceilings should be clean, floors being carefully inspected as regards freedom from litter and absence of pools of water, while both the walls and ceilings should be maintained in a satisfactory state of repair. Lighting, both natural and artificial, should be sufficient, and there should be no unpleasant odours in any part of the premises. The external area surrounding the plant should be free from rubbish, while refuse should be stored in suitable metal containers and not dumped in any odd corner of the yard. These containers should always be kept covered. The drainage system should also be inspected and should be of sufficient capacity to remove the large quantities of water employed.

The *water supply* is important. If the water used is obtained from a mains supply, it should be normally subject to periodical sampling and some proof of its quality will therefore be available. On account of the large amounts required for processing purposes, however, many large dairies draw their supplies from wells sunk on or adjacent to the premises. In such cases, frequent bacteriological and chemical samples must be taken. In one instance, known to the author, water at a processing plant, which was used for milk cooling and churn washing, was pumped from a polluted ditch adjoining the premises. Water used for dairy purposes should possess absolute bacteriological and chemical purity and should be free from dirt, sediment, scale and other physical defects. Water softeners and filters should be inspected as to their condition.

Cloakroom accommodation, which should be an essential feature of every plant, must not be overlooked. Urinals, closet accommodation and lavatory basins should be kept in clean condition. Particularly important is the provision of soap, nail brushes, towels and, last but not least, a constant supply of hot water. These articles are extremely important and they are often overlooked by the operator. A clearly visible and readable notice should invariably be exhibited in all cloakrooms regarding the washing of hands before any work is re-commenced. Opening windows should be noted and the cloakrooms should be separated from the plant proper by ventilated vestibules. Doors should be self-closing and in working order.

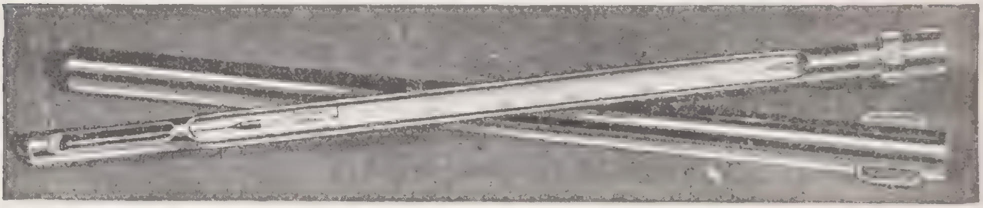
(*b*) LOW-TEMPERATURE PASTEURISING PLANT. The primary aim of plant inspection is to ensure that all milk is treated in a manner which complies with the various statutory requirements in force. Briefly, it must be emphasised again that all pasteurising operations should be carried out by skilled technicians, using apparatus designed and approved for the purpose, while the human element should be eliminated as completely as possible by the provision of automatic controls and temperature recorders. Log books should always be provided in order that complete records of all processing operations are available for inspection by the controlling official. Inspections should be carried out not only during working hours when the plant is operating, but also when no milk is passing through, preferably after the apparatus has been cleansed and sterilised.

All milk containers such as *receiving or storage tanks, heaters, filters* and *holders*, must be subjected to thorough inspection. Internal surfaces should be smooth and clean and if tinned copper apparatus is employed for any purpose, such surfaces should be well coated with tin and show no signs of the underlying copper base. There should be no open seams and the self-drainage of the apparatus after cleansing is an essential requirement. All plant should be maintained in good repair while thermometers which are submerged in milk should possess pressure-tight seats. *Milk pumps* are a common source of contamination. They should be easy to dismantle for cleansing purposes and in all cases where a rotating shaft is inserted through a surface with which milk comes into contact, the inspector should satisfy himself that the joints between the moving and stationary portions of the pump fit closely. There should be an entire absence of frothing of the milk through pumping, neither should glands nor stuffing boxes come into contact with the liquid. Rubber gaskets should be inspected periodically for wear and for cleanliness.

Pipe-lines should also receive the inspector's careful attention. All sections of pipe-lines must be of smooth bore and possess no unnecessary angles in order to facilitate easy cleansing. Bent or dented pipes should not be retained in use, milk solids being difficult to remove from their internal surfaces, while defective pipes assist in the rapid accumulation of " milk-stone." Pipe-lines should be easily dissembled for cleansing and any single section should not be more than 6 feet in length in order to afford ease of handling. A minimum length of pipe-line should be considered an advantage, while the attention of the operator should always be drawn to any leaking joints.

Valves are extremely important, as unless properly designed, operated and maintained, considerable trouble with the final product is likely to ensue. If the holding time is regulated by mechanical means, the efficiency of the mechanical regulation apparatus requires to be periodically checked as regards timing and in order to discover any inefficiency which may have developed. Inefficient valves will allow raw milk to leak forward into the holder compartments either during periods when milk is retained or while the pasteurised product is being discharged to the cooler. In addition, raw or incompletely pasteurised milk may leak into the outlet pipe-lines during heating, filling or holding. All valves should be provided with a suitable device which will prevent any leakage of milk when they are closed. " Batch " pasteurisers should be entirely disconnected from the raw milk supplies during holding periods unless this type of valve is provided, while they should invariably be provided for all multi-compartment holders. All valve adjustments should be checked for accuracy and for wear, as such faults may frequently be discovered during inspection. Leakages are often difficult to trace and in this connection a phosphatase test of milk taken from the holder at the time of discharge and of the first liquid to be discharged will indicate whether any leakages are taking place.

The *temperature* to which the milk is heated and subsequently cooled is of vital importance as regards the quality of the final product and this has already received repeated emphasis. It is often found that employees do not fully realise either the importance or the necessity for correct temperature maintenance. Watch must be kept for any intentional reduction in holding periods as a means of speedy treatment. This is usually due to the need for obtaining an increased output from inadequate plant, while thermometers and temperature recorders may not be operating in an accurate manner. With properly designed automatic plants, this reduction in holding time rarely occurs, but it is not uncommon when manual control is practised. Unscrupulous operators have been known to use the holding compartments as balance tanks, and this possibility should always receive the attention of the inspecting official. The growth of this practice is due, in many instances, to the increased quantity of milk requiring to be treated and the capacity for handling the daily amount of milk received at the plant should be enquired into.



By courtesy of Negretti and Zambra.

Fig. 69. Dairy Test Thermometer.

Indicating thermometers should be checked at least once weekly, although many dairies carry out a daily check, a standard test thermometer reading to within 0·2° F. being employed for the purpose. This procedure is extremely important as the Ministry of Health have recommended that the accuracy of heating thermometers shall be plus or minus 0·2° F., between 145° and 150° F. It is essential also that the thermometer used for testing shall have been certified by the National Physical Laboratory. The Negretti and Zambra dairy test thermometer, illustrated in Fig. 69, has been designed to comply with the above-mentioned requirements. This instrument is approximately 10 inches in length and possesses a range of between 140° to 155° F. or 150° to 170° F. with widely-spaced divisions so that readings to 0·2° F. can be quite simply made. It will withstand the high temperatures involved and is certified by the National Physical Laboratory, who issue a certificate of corrections with each instrument. The thermometer is used without the stainless-steel case which is provided for its protection. The time-lag of all indicating thermometers should be checked by inserting in a water-bath at 160° to 165° F. The time required for the reading to rise from 140° to 155° F. should not be more than 4 seconds.

Both indicating and recording thermometers can be tested by immersing their bulbs in a pail containing not less than 3 to 4 gallons of hot water, the temperature of which should be approximately 160° to 165° F. Care should be taken to ensure that the bulbs when immersed do not touch the sides of the pail, while this vessel itself should not be placed in such a position as will cause premature cooling of its contents. The bulb of the testing thermometer is covered to a depth of about 3 inches, a mark being engraved on the instrument at this point, while the water is circulated throughout the entire operation until a steady reading is indicated by both instruments. The temperatures indicated by the thermometer under test and by the testing thermometer are noted, the operation being repeated until a constant relationship is shown. Certain precautions are necessary when thermometers are being tested. It must be borne in mind that the rate of response at a given temperature varies greatly as between one thermometer and another and a steady temperature in the water-bath should be maintained. When tests are being carried out, the thermometer bulb should be immersed up to the end of the thread on the screw wing-nut fitting. Each thermometer should be tested separately against the standard instrument and they must never be dealt with in batches. It is essential that any differences should be noted as, in the case of recording instruments, adjustments for correction can be made, while a differential correction is necessary for indicating thermometers. Any errors discovered should be marked on the cases of the thermometers, and should be noted in the laboratory records. The date and time of the test should also be noted and the records should indicate the extent of any error between recording and indicating thermometers. If any corrections require to be made, these also should be noted. Before any errors are amended, it is necessary to note the positioning of the bulb. Bad positioning, as mentioned on p. 120, is often the cause of errors in reading, and it is essential that the bulb of any thermometer should be completely immersed in the milk whose temperature is required. It should be noted that thermometer bulbs require to be sterilised before they are refitted into the plant.

Indicating thermometers should always be employed to check temperatures under working conditions, and careful comparisons between the temperatures shown and those penned by the recording instruments should be made. At no time should the temperature recorded be higher than that shown by the indicating thermometer, with a deviation of not more than 1° F.

Temperature recorders must be periodically checked and the charts perused. These instruments should be kept locked to prevent any interference, the charts being retained for at least three months after use. On being removed from the apparatus they should be signed and dated by the person in charge, while, in addition, it is advisable that the location of the particular recorder to which the chart applies and the temperature shown by the corresponding indicating thermometer should also be shown. Recording thermometers are often found to be out of adjustment and charts are sometimes erroneously dated. All indicating and recording thermometers should be placed so as to be clearly visible and in good light, while it must again be emphasised that charts should be provided with sufficiently large scales. Separate recording instruments should be provided for each tank of "Batch" pasteurisers.

The temperatures of milk in various stages of processing should be carefully checked by the inspector, together with the holding time. Heating at too low a temperature is often due to the plant operator's desire to maintain the cream-line of his product. *Automatic discharge systems* from a series of holders or compartments require to be investigated, thermostatic control, which requires periodical checking, being usually provided. The control arrangements should be designed so that *all* milk is heated to, and held at, the requisite temperature.

Tipping tanks should possess means of protection from dust and oil droppings from adjacent machinery while close attention must be paid to *filters*. The cloths must be maintained in clean condition and frequently changed, while filtration pressures should be inquired into and, if excessive, should be reduced. In the *preheater*, there should be complete separation of milk from the heating agent, or, if regeneration is employed, from the pasteurised product. Temperature control at this point is important and both an indicating and a recording thermometer should be fitted. Once again it must be stressed that if the temperature of milk issuing from the preheater is close to 145° F., the temperature of the pasteurised liquid should be carefully checked. *Holders* should be covered, the covers being closed during processing, with no accumulations of milk or of water upon them. The insulation of the holders and their covers should be inquired into and noted and, if this appears to be insufficient, the temperature of milk leaving the holder should be carefully checked. This deficiency is a common cause of heat losses, particularly in the case of water-jacketed holders in which the heating agent is not thermostatically controlled. There should be no " dead-ends " or " cold pockets " in holding tanks while the surface of milk during treatment should be free from undue foam, even when agitation is provided. The milk in the different compartments of the holder must be entirely separated, while the overflow of any liquid from one compartment to another should be looked for, any backward leakage from the holder through inlet valves being checked to ensure that such milk really runs to waste and is not re-pasteurised. It should be noted whether or not all milk lies within the insulated area of the holder, a temperature check again being necessary if this is not so. In this connection it must be emphasised again that there should be no undue foam on the surface of the liquid and all possible precautions must be taken to ensure that any foam which is formed is maintained at pasteurising temperature. With vacuum-and-compressed-air plant, the air compressor, washer and filter should be examined as regards cleanliness and proper working order. *Balancing tanks* should be suitably covered, and no foam, if this is present on the cover, should be able to return to the tank. Separate tanks should always be provided for raw and for pasteurised milks, and the practice of storing milk in these tanks overnight should be strictly forbidden owing to the insufficient time which can be allowed for their sterilisation before they are again required for use.

(*c*) HIGH-TEMPERATURE SHORT-TIME PLANTS. The procedure just outlined deals with the inspection and supervision of low-temperature processing plants, apparatus dealing with milk by the short-time process requiring a different procedure. On account of the small margin of safety provided, extreme care is necessary in dealing with such apparatus, and the inspector should assure himself that the plant has been properly installed and that it operates efficiently at all times.

Once an application has been received by the licensing authority for a licence to produce pasteurised or heat-treated milk by this process and plant installation has been completed, steps must be taken to ensure that the apparatus is capable of producing continually a satisfactory article. Before any milk is treated for human consumption, every portion of the apparatus should be examined and checked and the inspector should be satisfied that operation is likely to be satisfactory. The approval of licensing authorities and their officials to the employment of such plants without prior checking is open to serious criticism, although it is a mistake which is commonly made and one which is often due to over-reliance upon either the makers' or plant owners' statements as to the efficiency of the apparatus and to lack of knowledge as to where faults may lie. Within the author's knowledge, one short-time processing plant was licensed to produce heat-treated milk which obtained its cooling water from a highly-polluted ditch.

Before dealing with the points where careful checking is required, it is necessary to set out the items which, when *fully* and *continuously* complied with, will satisfy the inspecting official that the installation is properly erected and operating in a satisfactory manner. All recording and indicating thermometers must be tested for time-lag and found to be accurate in accordance with the methods of testing set out on p. 234. The flow-diversion pen must be in perfect working condition and should record every diversion of milk from the forward flow to the raw milk tank or pipe-line. It is often found that the operating staff are not fully conversant with this part of the recording apparatus or with its correct use. The retarding period must be checked in accordance with the methods outlined on p. 240, while the diversion adjustment must be set so as to divert all milk, whose temperature falls below 162° F., back to the raw milk tank. It is essential to ensure that the cut-out which is provided works properly when the milk temperature falls below the requisite level, and any sub-temperature liquid may either be drained from the valve to be collected in some receptacle or, alternatively, it may be allowed to return to the apparatus for further treatment. Most modern short-time plants allow the milk to return to the raw milk pipe-line, although it is a debatable point as to whether or not such provision infringes the prescribed conditions which state that no milk must be re-heated. In any case, the entire discharge of the milk from the apparatus is not so drastic as it may appear. Apparatus now obtainable is exceedingly trustworthy and very little sub-temperature milk requires diversion from the plant.

The variable-speed pump must be adjusted and sealed to ensure continuously a holding period of not less than 15 seconds. In dealing with belt-driven pumps, any wear or stretching of the belt is likely to cause variations in speed. It is important that the pressure on the pasteurised milk side of the plates of a regenerator should at all times be greater than the pressure upon the raw milk side, and at the commencement of the run suitable pressures should be established by passing water through prior to the entrance of any milk. It is advisable also to retain a sufficient head of pasteurised milk in the regenerator in order to maintain a milk level for 1 hour after the plant is shut down. When tube retarders are installed, the tubes should slope upwards from inlet to outlet, this inclination being approximately half an inch to the foot, as low points, except at the inlet end, tend to trap air and reduce the retarding period. Bell-type or concentric fittings should be employed at the ends of the holder tubes so that their slope may not be improperly altered.

There should be an entire absence of milk or air leaks as any air drawn into the apparatus will reduce milk capacity, while no milk should leak forward while the valve is in a diversion position. It is necessary to maintain a constant head of milk in the surge tank and if a pre-determined accurate check of the actual holding period is made the measured capacity should correspond exactly with the calculated capacity of the retarding portion of the apparatus. If the holding chamber or tube possesses a capacity of 50 lbs. of milk and the retarding period, as regulated by the pump, is the required 15 seconds, the delivery rate would be 12,000 lbs. of milk per hour. Any variation in delivery weight, which might be discovered at a subsequent test, would indicate that the apparatus was not properly operating. As the frequent diversion of the milk is undesirable, the temperature controller should operate smoothly in order to ensure a steady flow of liquid at the requisite temperature. The assembly of the controlling pump should ensure that it is airtight, but it should be noted that worn bearings will decrease its capacity. It is important that all draw-off openings should be accurately labelled so that the temperature of any milk which may be obtained from such apertures is plainly indicated. No diversion valve should cease to function once the milk has been diverted until 30 seconds have elapsed.

Once the plant has been installed and tested by the manufacturer, the licensing authority should be ready to carry out its own inspection and series of tests. The *level of any holding tubes* should be checked, adjustments being made when necessary, while *gaskets* must receive careful inspection so that air leaks are obviated. It would be advisable for vacuum gauges to be fitted at different points in the system to detect such leaks should they develop. The *accuracy of thermometers* is extremely important. An accurate test thermometer should be inserted in the apparatus at points requiring to be tested and water at a temperature of 162° F. should be circulated through the plant until the water temperature has been stabilised when the indicating thermometer fitted should be checked against a suitable test thermometer. In addition, the recording thermometer should be tested in a similar manner, the water temperature being raised above 162° F. to prevent any diversion taking place while testing is in progress. If necessary, adjustments should be made to this instrument.

The *diversion temperature* must be checked by the circulation of water at a temperature slightly above 162° F. This temperature should then be slowly reduced until the diversion point is found. If this is too high or too low, the diversion controller should be adjusted and this should be sealed once the correct diversion point is found.

The *holding time* can now be checked, sufficient water being supplied to the raw milk tank to prevent any air entering the apparatus. All plants should be provided with suitable fitments to allow the necessary tests to be carried out, and before any water test is made, new filter media must be fitted while, in addition, operating conditions must be similar. A small measured charge of methylene-blue solution should be pumped into the holder inlet and the time taken for this solution to reach the pet cock fixed at the outlet of the retarding chamber or holding tube should be checked by means of a stop watch. It is advisable that several readings at intervals of 10, 12, 15, 17, 20, 23, 25 and 30 seconds should be made. A piece of white paper may be used as a background at the outlet and the first indication of colour should be considered the end point of the test. Another extremely accurate method of testing is by the injection of nickel ammonium sulphate solution through a spring-loaded injector. Tubes are filled with the solution issuing from the pet cock at the intervals set out above and dimethyl-glyoxime is used as an indicator. A more accurate method of testing is carried out by means of salt and a galvanometer. A high-pressure cylinder, holding 2 quarts and fitted with an air gauge is employed, a quart of saturated salt solution being placed in the cylinder which is attached to the retarding section of the apparatus. Air is pumped in until 80 lbs. pressure is registered and this will release approximately 20 ml. of the solution. A galvanometer whose contact points have been enlarged with light sheet copper to increase sensitivity is used. This is fixed into the holding section through the indicating thermometer aperture and water, at a temperature slightly above 162° F., is circulated. The salt solution is then injected. The time of injection and the time at which the galvanometer indicates the presence of salt are then noted. At least five tests should be made before any licence is granted, readings being taken at the intervals set out above.

Similar tests should be applied to the plant at monthly intervals and the product after treatment should be submitted to the phosphatase test at least once weekly. It must be emphasised that this latter test alone must never be used to judge the efficiency of a short-time processing plant. The tests and methods of inspection outlined above are essential if satisfactory control is to be maintained and the safety of the final product guaranteed.

(*d*) Cooling and Bottling Plant. The inspection of *coolers* should be devoted to ascertaining that milk is not in any danger of re-contamination following their use. Many open coolers are still employed and it cannot be too often emphasised that the protection of the liquid during this process is particularly important as, owing to the destruction of the majority of lactic-acid organisms present in the original milk, extraneous bacteria introduced at this stage of treatment are provided with special opportunities for development. Care should be taken to ensure that no condensed moisture accumulates upon the header ends of this type of cooler from where it is able to drip into the milk. This trouble may be overcome by shortening the bottom trough. Open-surface coolers should be placed in a well-ventilated room apart from the rest of the plant and should be equipped with tight-fittings shields. Enclosed coolers of the heat-exchanger type should be tested for cleanliness after the plant has ceased to operate and cleansing has been completed, sterile water being passed through the cooling section for this purpose. It should be remembered that pasteurised milk should travel through the heat-exchanger at a higher pressure than that of raw milk to prevent any possibility of the raw liquid or the cooling media leaking into the pasteurised product. Complete separation of the cooling agent and the processed milk is of extreme importance.

Bottle-filling machines should not be overlooked when an inspection is carried out as they are potential sources of re-contamination. Supply tanks and the collecting bowls of fillers should be protected with tight-fitting covers and these should be always kept in place. The length of time which elapses between filling and sealing should be noted and this period must be reduced to a minimum. Cleanliness should not, of course, be overlooked. The float in the feed tank should be adjustable while the apparatus is in operation, without any necessity for removing the protecting cover, while the filled bottles should be clean in appearance, properly capped and free from foreign matter and sediment.

(*e*) BOTTLE-WASHING MACHINES. *Bottle-washing machines* should supply clean bottles, each containing not more than 200 to 1,200 bacteria per container according to capacity while not more than 2 coliform organisms should be present in any size of bottle (see page 269). After treatment, they should be bright in appearance and free from film. These machines should be inspected for any faults likely to occur, the chief of these being choked steam, water or detergent jets, which should be examined frequently to ensure they are in proper working order. The water pressure should always be checked when a mains supply is used. Poor pressure will reduce the scrubbing action of the jets and some type of booster may be necessary. Pre-rinsing jets are most likely to become choked with *débris*, solids and other materials, particularly if the rinsing water is re-circulated. Tanks should be emptied, strainers cleansed and inspected in all cases and they should be kept clear of any *débris* likely to cause blockage of the mesh. *Débris* and broken glass should always be removed at the end of each day's run. Any large quantity of broken glass should be noted as an accumulation of this material may be due to excessive temperature changes between the various sections of the apparatus. The correct centring of the jets may be required to correct unsatisfactory treatment. Excessive re-circulation cannot be recommended as material which escapes pre-rinsing may be carried forward to foul the detergent solution in the soaking tanks. Jets opening out at the delivery end are less likely to become choked although, with this type, the pressure effect upon the internal surfaces of the bottles is not so great as when the orifice is narrow. As the warm final rinse is usually re-circulated, its bacteriological condition may be unsatisfactory, and although a sufficiently strong detergent has been employed, its work will be rendered useless on this account. Rinsing tanks should always be inspected as in jet-operated plant a daily cleansing is desirable although, with soaker-type apparatus, expense may probably prevent cleansing more often than two or three times weekly. Too low temperatures, which should be carefully checked, and too weak detergent solutions are other causes of unsatisfactory washing.

All brushes and mechanical parts should be examined for wear, and should be immediately renewed as and when necessary. Proper adjustment in order to avoid damage to bottles is essential. One great fault of dairy operators is the manner which they allow the detergent to become so weak that it is almost useless for the purpose for which it is intended. This is an economy measure which must be prohibited as soon as discovered and the inspector should always make inquiries as to the strength of the detergent and frequently obtain samples for subsequent laboratory examination. The conveyor for delivering clean bottles to filling machines should be covered to prevent any moisture or foreign bodies entering the containers. All indicating and recording thermometers showing the temperatures of the various operations should be frequently checked against a standard thermometer.

Bottles and *churns* on leaving washing machines should be inspected carefully and frequently tested for presence of organisms by means of sterile water. Containers may appear clean and bright although numerous micro-organisms may be adhering to their internal surfaces. The test for commercial sterility, the final proof of efficient treatment, is carried out by means of a rinsing test detailed on p. 268, while the standards required are also set out thereon. Bottles and churns subjected to such examinations should be selected at random from each batch treated. Unsatisfactory bacteriological results will, if detergent and other internal factors are satisfactory, probably be due to re-contamination after treatment, usually by the final rinsing water, while failure to select the extremely dirty bottles for separate treatment and lack of inspection of the washed bottles leaving the machine are often causes of poor results. Water softeners of the base-exchange type may cause bacterial contamination if they are not chlorinated occasionally, while leakages and the splashing of pre-rinsing water and detergent into final rinsing water tanks may also be a source of trouble.

Bottles during storage should be protected from subsequent contamination and floors of rooms in which the containers are kept should be frequently washed down. Caps or covers for bottles, or the rolls of foil from which they are fabricated, should be kept in their original tubes and cartons until required for use. Before operations commence, the first two or three caps or discs should be discarded as they are likely to be contaminated with dust. *Crates* should never be overlooked as clean bottles are frequently loaded into crates which have not been cleansed.

Delivery vehicles should be kept clean and tidy, and should, from a commercial point of view, possess an attractive appearance. Nothing should be carried on such vehicles which is likely to contaminate the milk.

(*f*) PERSONNEL. The *health of personnel* operating the plant and of those persons engaged in distribution should be the subject of careful enquiry. Coughing, sneezing or spitting should be discouraged in any part of the premises and personal cleanliness should be insisted upon at all times. It would be advisable, indeed it should be compulsory, for all employees to undergo a thorough medical examination at frequent intervals. If this practice was carried out, the employee's medical history with particular reference to attacks of enteric fever, dysentery, diphtheria or scarlet fever should be inquired into, while a thorough examination as regards pulmonary tuberculosis must be considered an essential requirement. A bacteriological examination of swabs from nose and throat, also of sputum, together with a similar examination of specimens of urine and faeces would also be necessary. The failure of plant operators and licensing authorities to control in a suitable manner the health of personnel employed at milk depots has caused the infection of pasteurised supplies on more than one occasion. Although there is no available power to enforce a medical examination at the present time, much can be done by the plant owner in this respect and powers of enforcement ought certainly to be granted to all licensing authorities. Cases of infectious disease, either on farms supplying raw milk to the plant or at the homes of the operatives, should be reported immediately to the licensing authority which has supervisory control of the plant, in order that it may take any necessary action. White overalls and head coverings should be provided and it should be an instruction that these must be worn at all times. Frequent changes and laundering to keep such garments in clean condition are necessary. Particular attention should be paid to the hands of the operatives, who should be required to keep them in a suitable condition.

CHAPTER XIII

LABORATORY CONTROL

THE control of processed milks in the laboratory must be exercised in conjunction with plant inspection and certain laboratory tests are necessary for this purpose, not only for determining the final condition of the treated milk but also for checking the efficiency of utensil sterilisation and the quality of the untreated liquid prior to pasteurisation.

The inspector should check the temperature of the cooled milk, both in the plant, in storage and during delivery, by means of a pocket thermometer. The liquid should also be examined for taste, flavour and appearance while the state of the bottle and its contents should be noted. Samples should, of course, be submitted frequently for chemical examination, but from the point of view of process control, this is not so important as bacteriological and other tests. Line-test samples, taken at various points in the plant, should also be obtained for subsequent laboratory examination. It must always be borne in mind that the laboratory control of processing acts as a supplement to the visual inspection of the various sections of the plant. Such examinations ought to yield a fair indication of the quality of the finished article and give both the operator and the inspector a guide to the quality of the milk which is being distributed. Samples may be obtained at the plant in order to test the efficiency of processing, or during delivery to the consumer for the purpose of ascertaining if any contamination has occurred after pasteurisation.

Laboratory Accommodation. A laboratory is a necessary adjunct to all processing plants and milk collecting stations in order that the incoming supplies, the final product and the general efficiency of processing may be controlled. It requires to be suitably equipped and staffed with trained personnel. It is particularly important that the laboratory should be situated adjacent to the processing rooms *and* the receiving platform in order that samples for testing may be quickly secured. The room should be well lighted, clean and quiet while north light is necessary. The size and arrangement depends upon the number and types of tests to be carried out but sufficient space to allow ease of working is essential, while separate rooms for bacteriological and chemical examinations should always be provided. It should be stressed that all equipment must be of the highest quality. If the cold room of the plant is situated at some distance from the laboratory, a refrigerator should always be provided for the storage of reagents and for samples awaiting test.

Collection of Samples. It is essential that all samples of milk should be collected in accordance with the recognised principles laid down by the Ministers of Agriculture and Health. *Bulk supplies* require to be obtained with particular care, and these are usually taken from churns after they have been unloaded on to the delivery platforms of dairy premises. It is particularly important that a representative sample should be obtained as it has been proved that the largest number of organisms are found in bulked milk towards the top of the churn, particularly if the liquid has been standing for some time. If separate samples are obtained from the base, middle and upper portion of a full churn, the sample taken from the top will show the highest bacterial content while the lowest number of organisms will be found in milk which is obtained from the lower portion of the churn. It must be borne in mind that the more fat milk contains, the higher will be the bacterial content of the sample, unless the liquid has been thoroughly mixed before sampling has taken place. It is essential, therefore, that before any samples are obtained from such containers the milk from which the samples are to be taken should be thoroughly mixed by means of a sterile plunger, which should be inserted into the liquid and plunged upwards and downwards for at least five seconds. It must be emphasised that a standard method of mixing milk is as important as a standardised method of sampling.

A considerable amount of *bulked milk in road and rail tanks* is despatched from country collecting stations and received daily at large processing depots, and samples collected from such containers require special care. In the case of those obtained from tanks *before despatch*, sampling must be carried out within 30 minutes of the completion of loading. The milk should be plunged vigorously for 5 minutes by means of a 16-inch plunger which is provided with a handle at least 6 feet in length. When samples are required to be taken from milk tanks *at the point of* *arrival*, the milk should be plunged vigorously for 15 minutes before any sample is obtained. If such samples cannot be tested within 30 minutes of sampling, the bottle and its contents should be immersed in water at a temperature below 40° F. for 15 minutes and held at temperatures between 32° and 40° F. for not more than 18 hours. Once obtained, samples from tanks are usually submitted to the ten-minute resazurin test (see p. 256), and to a test to ascertain titratable acidity (p. 271). The particulars which should be recorded are the temperature of the milk after plunging, the date and time of sampling and testing and the number of the tanker. All samples should be obtained from well below the surface of the liquid to be tested.

When samples are taken from the *weigh tank* at a dairy, it is sometimes assumed that the violent agitation to which the milk is subjected when poured from the churns will adequately mix the liquid. Experiments have shown, however, that there are large differences in the fat distribution in milk which has been treated in this manner, and for this reason the sampling of raw milk from the weigh tank should never be practised if this can be avoided.

Wide-mouthed, glass bottles, each of 3 fluid ounces capacity, stainless steel or tinned copper milk dippers of a similar capacity contained in metal cases and stainless metal plungers with detachable or folding handles are required and each bottle should be provided with a metal screw cap or ground glass stopper. A useful sampling outfit comprises a portable metal case which holds both dippers and plungers. It is important that no part of the outfit which comes into contact with the milk should be touched by hand and that each dipper is provided with a pouring lip and possesses a hooked handle to loop over the fingers. Bottles, dippers and plungers, complete in their cases, require to be sterilised in a hot air oven at a temperature of 160° to 170° C. for two hours before they are used. Each dipper should not be more than 15 inches in length and should not be removed from its case until required for use. Three ounces of milk is obtained as this quantity of liquid assists in the elimination of possible errors in sampling which may be due to the uneven distribution of bacteria in the milk. The bottles, which should be filled as full as practicable in order to avoid churning the fat during transport, are packed in boxes made to hold four, six or eight samples and they should be immediately forwarded to the laboratory. That portion of the stopper which comes into contact with the milk should not be allowed to touch any unsterilised object, only the top of the closure coming into contact with the fingers.

In-the-line samples are collected by holding a sterilised sampling bottle under a draw-off opening and are dealt with in the manner set out above. It is extremely important to ensure that all draw-off openings or taps from which these samples are obtained are efficiently sterilised before any milk is collected from them. It should be emphasised that pipe-line joints must never be broken for sampling purposes. Samples obtained in the manner described above are of value as an indication of possible sources of contamination from the apparatus. For the correct comparison of results, the same batch of milk should be followed through the plant, and this procedure is only possible with the first liquid treated. The fluid washes any organisms from the internal surfaces of the apparatus and sampling the first batch of milk is the best method of checking the efficiency with which each section of the plant has been cleansed and sterilised.

The *sampling of milk in bottles* is comparatively easy. The sample should consist of one container with the seal unbroken, one ½-pint bottle usually being sufficient for this purpose, and it should be delivered intact to the laboratory. If desired, two bottles may be purchased and their contents mixed, but such mixing should only be carried out by the bacteriologist or his assistant. Samples may be obtained free of charge and should be taken at any point between the place of bottling and delivery to the consumer. It must be emphasised that samples of heat-treated and pasteurised milks should not be packed in ice for transport to the laboratory. The examination of samples of bottled pasteurised milk does not furnish the same information as that which is obtained from samples taken at different points in the plant during processing operations, but it does provide information as to the uniformity of the bacterial population present and shows if any increase in the bacterial content has occurred following treatment. Information is also provided as to the extent of any re-contamination as indicated by comparison with the results shown from the examination of raw milk entering the plant and the samples obtained from the plant itself.

Recording of Particulars. The following particulars regarding each sample should be noted :—

(*a*) Type of sample.
(*b*) Date and time of sampling.
(*c*) Producer's name and address.
(*d*) Retailer's name and address.
(*e*) Where sample obtained.
(*f*) Point in plant at which obtained in case of in-line samples.
(*g*) Date and time of production.

Resazurin Test. It is impossible to pasteurise efficiently milk which has not been produced in a satisfactory manner, and this point cannot be too often emphasised. Pasteurisation does not sterilise milk, nor will it render dirty milk clean. It must again be reiterated that the process merely reduces very considerably the numbers of bacteria present and, if efficiently carried out, will also destroy any pathogenic organisms which the liquid may contain. In order to ensure that the milk received at the plant is suitable for treatment, it is essential to employ either the resazurin or the methylene-blue tests (see p. 258). These are not competing tests but are complementary to each other as each detects certain faults in the liquid submitted to such examination, the selection of the test employed depending upon how the milk is to be used. The methylene-blue test is of primary importance in assessing the bacterial content of a sample. The resazurin test, however, is more sensitive to high cell counts which are frequently due to the presence of mastitis in herds and which indicate the presence of organisms likely to affect treatment while it assists in eliminating milk of poor keeping quality from the bulk supplies. The resazurin test is, therefore, of greater importance to those using milk for processing and has therefore been generally adopted as a general routine test, not only for the reasons outlined above, but also as an inducement to farmers to produce a cleaner article.

It is essential that the milk should be examined as received at the plant in order to avoid processing a liquid which is likely to endanger the entire final product from the standpoint of quality. Milk may suffer from quality defects such as physical dirt or absorbed odours that do not become more pronounced as time progresses, irrespective of the period during which the milk may be kept. There are, however, bacterial defects that are likely to become progressively worse, thereby endangering the keeping quality of the product and rendering it quite unfit for processing. For this reason, the employment of the resazurin test is essential to assist in the selection of milk suitable for processing from among the supplies received at the depot.

For several years now, the methylene-blue test has been acknowledged as the most suitable method of determining the activities of organisms present in raw milk. Although a reasonably quick result is afforded by its employment, the reduction of the resazurin dye can be even more speedy according to the method of testing employed. Resazurin is more quickly reduced by the weak reducing systems which are present in milk, whether these are produced by bacteria or are inherent in the liquid. During the test, the resazurin-milk mixture changes from its blue original colour, through mauve to pink, and finally, in the case of extremely bad samples, to white while this colour change is irreversible. The colour developed at the end of the standard test is dependent upon the initial bacterial contamination, the amount of bacterial development during the incubation period, the reducing tendencies of the organisms and any abnormal characteristics of the milk.

Certain *precautions as to sampling* milk obtained for this test require to be observed. Samples should be taken from the churns within one hour of arrival at the plant, while long handled dippers (15-inch handle) of at least 3 ounces capacity are employed for sampling. Before any sample is obtained, the milk in the churn should be well stirred and plunged with the dipper for five seconds and the sample should be taken well below the surface of the liquid. After each separate sample has been obtained, the dipper should be rinsed in cold water and afterwards sterilised in boiling water up to within 3 inches of the end of the handle for not less than 30 seconds. If a composite sample is taken from two churns, the dipper does not require to be sterilised between sampling. On arrival at the laboratory, the milk should be stored in the following manner :—

(*a*) *P.M. and Mixed (E.M.X.) Milk.* Maintained at atmospheric shade temperature from the time of sampling until 4 p.m. on the day following production of the P.M. milk. Any samples not tested by this time should be cooled by submenrsion in water at a temperature of 40° F. or less for 15 minutes, placed in cold storage at a temperature of 32° to 40° F. until 9 a.m. the following morning and then immediately tested.

(*b*) *A. M. and Mixed* (*M.E.X.*) *Milk*. Maintained at atmospheric shade temperature until 9 a.m. on the day following production and then tested.

If the samples freeze during cold storage, they should be placed in a water-bath and held at 18° C. for 30 minutes immediately prior to any test being made.

The following particulars regarding each sample must be recorded :—

(1) Name or code number of producer and address of premises.
(2) Laboratory number of sample.
(3) Time of milking (A.M., P.M. or mixed).
(4) Time of sampling.

A suitable book for recording particulars of samples as they are obtained should bear the following headings :—

(1) Laboratory sample No.
(2) Name, address and number of producer.
(3) Gallons of milk in churn.
(4) Time of milking (A.M., P.M. or mixed).
(5) Time test is commenced.
(6) Mean of maximum and minimum shade temperatures.
(7) Result of test (ten-minutes or standard).
(8) Remarks.
(9) Action taken.
(10) Name of person making test.

The *apparatus* required consists of :—

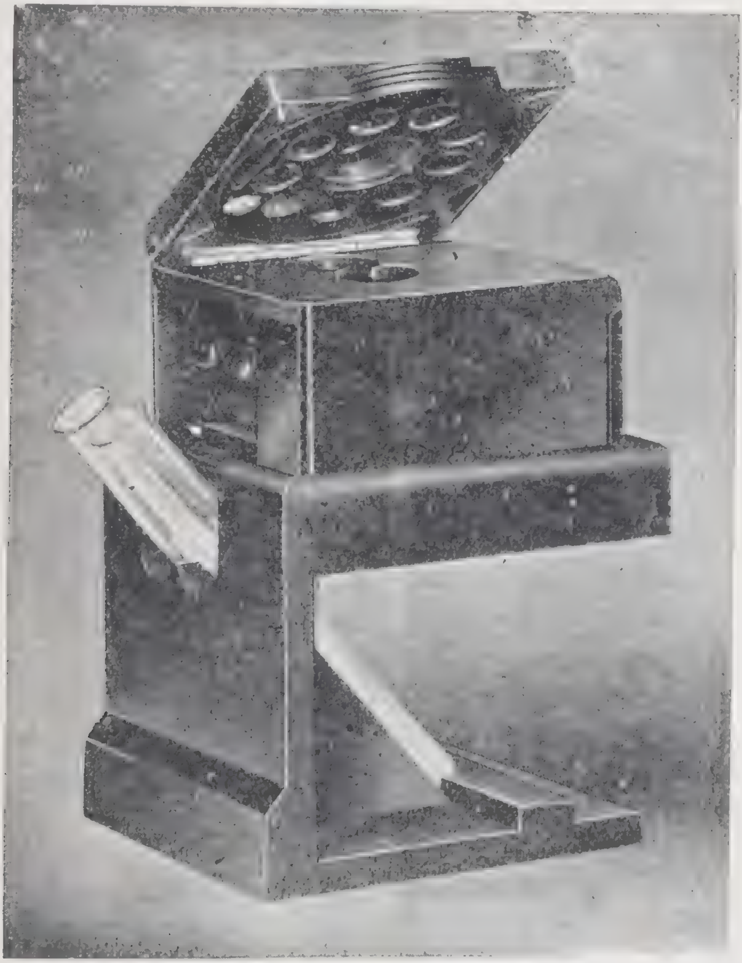
(*a*) An all-purpose Lovibond Comparator as shown in Fig. 70. This is fitted on a special stand and the same apparatus, with certain modifications, can be used for the phosphatase test if desired.

(*b*) The Resazurin disc. This contains seven empirical colour-glass standards which range from blue through mauve to pink and finally colourless.

(*c*) A water-bath which is thermostatically controlled to maintain a temperature of 37° C. This is a standard apparatus and is constructed of copper, being heated by oil, gas or electricity as desired. Its temperature must be maintained between 37° and 38° C. and the interior of the bath requires to be kept dark while it should be fitted with a test-tube rack numbered for identification purposes and provided with a metal cover (see Fig. 71).

(*d*) Test-tubes (6" × ⅝") etched at the 10-millilitre mark and a 1 millilitre pipette. All tubes should be made of glass of standardised thickness and should be of similar colour. They should be provided with rubber stoppers for sealing purposes.

(*e*) Resazurin solution. This may be prepared from stock solution or from standardised resazurin tablets. The solution used for testing is made up by diluting 0·05 per cent. stock solution with 10 volumes of sterile, glass-distilled water to make the 0·005 per cent. bench solution or by dissolving one standardised tablet in 50 millilitres of cold sterile glass-distilled water. Stock solution should be stored in a refrigerator.

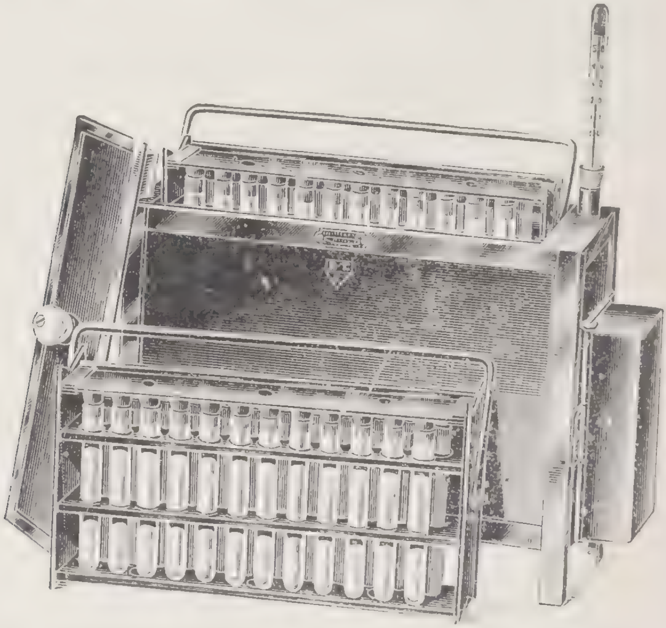


By courtesy of The Tintometer, Ltd.

FIG. 70. Lovibond All-purposes Comparator. (Used for Phosphatase and Resazurin Tests.)

The *standard resazurin test* is the more exacting of the two, and the results obtained are more reliable. A test-tube is filled with

10 millilitres of well-mixed and aerated milk to the graduate mark, the mouth of the sample bottle and of the test-tube bein flamed. One millilitre of resazurin solution (0·005 per cent.) i added and the tube sealed by means of a sterile rubber stoppe The tube and its contents are then inverted twice after which i is placed in a water-bath maintained at 37·5 ± 0·5° C. an



By courtesy of Baird and Tatlock, Ltd

Fig. 71. Water-bath.

incubated in accordance with the times set out in Table below.

Table 4

Compensation Scale

Mean of Maximum and Minimum Shade Temperatures.	Period of Incubation at 37° C ± 0.5° C.
40° F. and under	120 minutes
Over 40° F. and up to and including 50° F.	90 ,,
,, 50° F. ,, ,, 55° F.	60 ,,
,, 55° F. ,, ,, 60° F.	30 ,,
,, 60° F.	15 ,,

Tubes which are incubated for 90 or 120 minutes must be inverted at the end of one hour.

At the expiration of the incubation period, each tube is removed, inverted once or twice, wiped and placed in the right-hand slot of the comparator so that it rests in the ramp as illustrated in Fig. 70 and comes below the colourless centre of the disc. The comparator should face a north window or towards a white wall or surface and should be placed at a height such as will enable the operator, when standing over it, to look directly down on to the two apertures. A tube containing the same amount of a similar coloured milk, without resazurin, is placed in the left-hand slot to act as a background for the colour-glass standards. When highly-coloured milks are to be tested, similar to those obtained from Channel Islands cattle, care must be taken to ensure that the milk in the "blank" tube possesses the same depth of colour, thus compensating for the variable and inherent colour of the liquid. The disc is revolved until the sample is matched, or until its colour falls between two standards and the reading noted. Samples should be matched on tint and not on intensity of colour. If the colour falls approximately half-way between two numbers, half the value should be recorded. It is extremely rare for accurate matching to be impossible. If the milk in the tube is white or possesses a shallow pink band on its upper surface, 0 should be recorded, while if the liquid exhibits a mottled, streaky, whitish-pink or very pale pink colour, ½ is recorded. If the samples are examined by normal electric light, results will be approximately one figure too high, and for this reason some form of daylight lighting or a Lovibond lamp unit should be employed. This latter apparatus consists of a fused, two-compartment glass cell which is fixed in a holder in front of the observation apertures of the comparator. Its two compartments are filled with blue and pink solutions of internationally-standardised C.I.E. formula and they correct yellow artificial light to within a very close approximation of north daylight. A 60 watt pearl lamp provides the illuminant and tests have shown that results obtained with this apparatus agree extremely well with those obtained by daylight. The results of the tests are interpreted as shown in Table 5.

The assessments include both bacterial quality and freedom from any abnormality in a pathological sense. The results of the tests are notified at quarterly intervals to the producers concerned by the Provincial Dairy Bacteriologist.

TABLE 5

Colour Glass No.	Quality.	Colour.	Procedure.	Category.
6 5 4	Excellent Very good Good	Blue Slightly mauve Mauve	Accepted for liquid milk market.	A
3 2 1	Fair Poor Bad	Pink-mauve Deep pink Pale pink	Readings between 3½ and 1 (both inclusive)—salvaged if possible, otherwise rejected.	B
0	Very bad	White	Readings ½ and 0 — to be returned to producer.	C

The *ten-minute platform rejection test*, which must be commenced within half an hour of the arrival of the milk at the premises, requires a technique similar to that described for the standard examination except that the tubes containing the samples are retained at a temperature of 37° ± 1·0° C. for 1 minutes ± 30 seconds only. Timing must be extremely accurate and at the completion of the test, if the colour indicated by the disc reading is less than 4, the milk is of poor quality. If the colour changes to pink (disc reading 3½ to 1 inclusive), an extremely low quality is indicated. Such milk should be salvaged if possible, but otherwise it may be returned to the producer, the final decision depending upon any facilities for utilisation which may be available. Milk showing disc readings of ½ and 0 is rejected.

Unsatisfactory results may be due to causes which are quite unrealised by the producers concerned, and they should never be accused of faulty production methods as the result of a single failure of milk to pass the test. It is recommended that thre tests should prove to be unsatisfactory before any restrictive action is taken. Milks which give results below standard 3 should be microscopically investigated, a smear being made from the milks in the offending tubes, which should be fixed and stained with methylene blue. Large numbers of bacteria indicate careless methods of production while evidence of leucocytes demonstrates the presence of mastitis, particularly if these organisms are present in conjunction with long-chained streptococci. It should be noted that any decrease in the intensity of the original blue colour is correlated with a high fat content and should not be taken as an indication of poor quality.

Certain *precautions* require to be observed when tests are made. After resazurin dye has been added to 10 tubes of milk, these should be sealed and placed in the water-bath before any more tubes are set up. With the ten-minute test, tubes should be dealt with in batches of five at one time. Disc glasses should be kept free from dust and moisture, and it is important that both tubes when examined should be equally illuminated and free from shadows, while the pipette used for the transference of the dye solution to the tubes of milk should *not* be introduced into the stock solution. A fresh, sterile pipette should be used for every batch of ten samples, and should one of these become contaminated in any manner it should be immediately discarded. The bench solution (0·005 per cent.) must always be freshly prepared for each day's work and neither solution nor the milk to which resazurin has been added must be exposed to direct sunlight. The interior of the water-bath must be kept dark and the level of the water should always be maintained above the level of the milk in the tubes. The temperature of the bath should be checked at half-hourly intervals while thermometers require to be tested monthly against a standard thermometer. All water-baths should be cleansed at weekly intervals, fresh water being added. It is important, also, that persons making the tests should possess normal colour perception.

As summarised by Davis, the *advantages* to be derived are that an accurate estimation of colour is possible and only one reading is required while a speedy result is obtained. Air does not affect reduction and mastitis is easily detected while the dye is sensitive to any organisms of weak reducing power and to the reducing influences of abnormal milks. Owing to the speed with which the result is obtained, particularly with the ten-minute metho contamination in sampling and in making the test, while i should be avoided, is not so important as is normally the cas This examination is more effective than is the methylene-blu test in detecting very poor milk, and the flora present at it termination approximates more closely to the initial flora tha when long incubation periods are employed. In addition, a complete reduction of the dye is effected, all the informatio which may be obtained from the methylene-blue test is availabl

This method may be utilised for *assessing the efficiency of th pasteurisation process*. Samples from bottles of pasteurised milk o in-line samples taken at various points in the plant can be dea with, the liquid being placed in test-tubes which are incubate at 18° C. for 24 hours. At the expiration of this period, the te is carried out in the manner already described except that th samples should remain in the water-bath for three hours, reading on the comparator being obtained at half-hourly intervals. I at the end of one-and-a-half hours the disc reading is less than such samples should be classed as unsatisfactory on account o contamination from unsterile surfaces, whilst if the reading ½ or 0 for the same period of incubation, this is an indication o gross contamination. Any marked change in consecutive in-lin samples taken from the plant indicates some fault between tw particular points and an investigation should be made. Normally with satisfactory treatment, no change should have taken pla at the expiration of three hours' incubation.

The resazurin test, suitably modified as regards temperatur may also be employed for the detection of unusually large numbe of thermophilic organisms (see p. 264), while, in addition, it useful for assessing the efficiency of plant sterilisation whe samples obtained at various points in the apparatus are examine

Methylene-blue Test. Both in this country and abroad, th method of testing has been used for a good many years as a mea of assessing the bacterial quality of milk. It is a legal requireme that the methylene-blue test shall be applied to all heat-treate or pasteurised milks respectively in accordance with the metho set out below. Milk which fails to decolourise the dye in 3 minutes is deemed to have satisfied statutory requirements. A compared with the plate count, formerly employed for the exami nation of pasteurised milks, the methylene-blue test possess distinct advantages. The experimental error is considerably smaller, the time of reduction does not appear to be affected by the clumping of bacteria, while it is more sensitive to bacterial growth.

The majority of organisms in milk are capable of altering the oxidation-potential of the liquid to a point at which the colour of certain dyes is discharged. This has already been considered in dealing with the resazurin test and methylene blue, one of the aniline dyes, is affected in a similar manner. The rate at which this change takes place varies considerably, and is related to the species of organisms present, their rate of growth and their activity at any one temperature. Generally speaking, it may be stated that the greater the number of organisms in a given quantity of milk and the more active they are, the shorter will be the time required for the reduction of the dye. It should always be remembered that this test is *not* a method of enumerating the bacterial population of a sample of milk, but is rather a *test of the activity of that population* at any particular time.

The *apparatus* required is much the same as that necessary for making the resazurin test and consists of :—

(*a*) A water-bath thermostatically controlled to maintain a temperature of 37·5 ± 0·5° C. This is similar to that employed for the resazurin test and is described on page 252 (Fig. 71).

(*b*) Test-tubes possessing an etched mark at the 10-ml. level and fitted with aluminium caps. These require to be sterilised in a hot air oven at a temperature of 160° C. for two hours.

(*c*) Rubber stoppers for sealing the tubes during the test, which must be sterilised in boiling water immediately before use.

(*d*) One-millilitre straight-sided pipettes which require to be plugged with cotton wool, wrapped in Kraft paper and sterilised in a similar manner to the test-tubes.

(3) Methylene-blue solution. This is prepared from standard tablets, one of these being dissolved in 200 ml. of cold, sterile, glass-distilled water in a sterile flask. The flask and its contents should be well shaken to dissolve the tablet, following which sufficient sterile distilled water is added to increase the quantity of solution to 800 ml. The flask should be sealed with a rubber stopper in order to prevent evaporation and stored in a dark place. Solutions over two months old should not be used. After the solution has been made up, its sterility should be checked, further tests requiring to be made at frequent intervals.

The *examination of the sample* is carried out in the following manner. The milk to be tested must be maintained at atmospheric shade temperature from the time of sampling until it is examined. This temperature must not exceed 65° F., and the test must be commenced between the hours of 9 a.m. and 10 a.m. on the day following that upon which the sample has been obtained. The milk to be examined is well mixed by inversion and shaking. The stopper and the mouth of the sample bottle should be flamed along with the test-tube, the well-mixed milk being poured rapidly in, until the liquid reaches the 10-ml. mark, care being taken to ensure that one side of the tube is left unwetted. One millilitre of methylene-blue solution is then added by means of a pipette, and this should not be allowed to touch the milk or the side of the tube. The tube is then sealed with a sterile rubber stopper and it is essential that the fingers should not touch its mouth during this insertion. The tube and its contents are twice inverted slowly, after which it is immediately placed in the water-bath. Two control tubes are required for each batch of samples examined. One of these contains 10 ml. of mixed milk from several samples plus 1 ml. of tap water while the other should be set up with 10 ml. of mixed milk plus 1 ml. of methylene-blue solution. These tubes are fitted with stoppers and must be immersed in boiling water for three minutes in order to destroy the reducing properties of the milk. Control tubes are necessary to denote the commencement of decolourisation and also the completion of this change.

The tubes which contain the milk to be tested are incubated for 30 minutes, care being taken to ensure that they are never exposed to direct sunlight and those which have lost their colour before the incubation period has ended should be removed from the bath. All tubes require to be inverted from time to time during the incubation period. Unless this is done, and if the cream content is allowed to collect upon the surface of the liquid, the reduction period will be delayed. A common but unsatisfactory method of inspecting the tubes is to examine the whole rackful *en bloc*, but if this is the normal practice, slight changes in colour may not be observed, especially if these inspections are made by artificia light. For this reason, each tube should be lifted individually for inspection and compared with the control tubes in a good light. Milk must be regarded as decolourised when the whole column of liquid has lost its colour or is decolourised up to within 5 mm. of the surface. The time at which decolourisation takes place is noted, but if no change has occurred within the prescribed time, the sample under examination complies with the test.

Certain *precautions* must be strictly observed in technique. The interior of the water-bath must always be kept dark during the progress of the test, and its temperature should be checked at frequent intervals. The thermometers on water-baths, as already mentioned, require to be checked at monthly intervals while the baths should be cleansed weekly and fresh water added.

The test possesses the *advantages* of being suitable for use by any intelligent person while a result is obtained within a short period of time. In addition, control may be exercised where laboratory facilities are limited and at a low cost. If the precautions detailed are strictly observed, the test is fairly foolproof.

Suitably modified as regards temperature, the methylene-blue test may be employed for the detection of unusually large numbers of thermophilic organisms (see p. 264).

The employment of this test for the *examination of pasteurised milk* aims mainly at detecting any re-contamination which may have occurred after treatment, due to inefficiently-sterilised surfaces, principally during cooling and bottling operations, and it also provides an estimation of the keeping quality of the milk in the hands of the consumer. The plate count, formerly used for the examination of pasteurised milks, has been the subject of much criticism owing to the variable results obtained from the examination of the same sample by different workers and also on account of the impossibility of obtaining adequate information as to the extent of any re-contamination except where gross errors in plant management had occurred. It is difficult to carry out and requires elaborate equipment while it does not bear any relation to the keeping quality of the liquid, the majority of the organisms present being thermophiles which exert little influence on keeping quality at ordinary household temperatures. The organisms which survive processing and which influence the keeping quality of the milk are present in small numbers only, and the aim of testing should be to assess the effect of these organisms. The methylene-blue test as applied to raw milk is not sufficiently sensitive for grading purposes when applied to the heated article, and for this reason it has been found necessary to age the milk to be tested by storing it for 24 hours at a temperature of 65° F. in order that those organisms, which are likely to cause the liquid to sour, may multiply so that their detection is rendered easy. In this manner, milks which have been indifferently or carelessly handled may be differentiated. Once a sample has been stored for this period, the methylene-blue test is carried out in the usual manner. There appears to be a close relationship between the reduction time and the coliform content of the milk.

This test, when applied to samples of milk obtained from different points in the plant, will be found useful for assessing the efficiency of plant sterilisation.

Coliform Examination. This test, when carried out in accordance with the technique laid down in Memo 139 Foods (January, 1937), is exceedingly useful for denoting inefficient processing or, more usually, re-contamination of the liquid after treatment, and it is one of the best methods available for evaluating the efficiency of pasteurisation, and also the condition of the bottles into which the milk has been filled. These organisms are almost totally destroyed by efficient pasteurisation and, if they are found to be present in 10-ml. quantities of milk immediately after processing, it is obvious that the methods employed are in need of immediate investigation. Samples obtained at various points in the plant, submitted to this test, will enable the direct point of contamination to be determined. The presence of such organisms in samples of milk taken during delivery almost certainly points to contamination after treatment. In carrying out the test, three tubes are set up, and it is suggested that not more than one tube should be positive. The test is useful mainly on the positive side, but a negative result does not necessarily indicate that processing is efficient.

Pathogenic Organisms. Both pasteurised and other heat-treated milks should be periodically examined for the presence of pathogenic organisms. The presence of such bacteria in processed milk indicates either that the temperature has been too low or that the liquid has not been retained for a sufficient length of time. If a sample has complied with the requirements of the phosphatase test, it is most unlikely that any pathogenic organisms will have survived treatment as the temperature attained and the period of retention are sufficient to destroy them. After contamination by the addition of infected raw milk or infection from members of the dairy personnel may be discovered, even when the phosphatase test has proved satisfactory. It is particularly important, therefore, that samples of processed milk should be subjected to guinea-pig inoculation for the presence of tubercle bacilli and examined for the other pathogenic organisms at regular intervals.

Thermophiles. *Thermophilic* (*heat-loving*) and *thermoduric* (*heat-resistant*) organisms are liable to be present in varying numbers in the majority of pasteurising and heat-treatment plants unless extreme care is exercised in their operation. Such bacteria are seldom found in bulked samples of raw milk, exceeding 2,000 per millilitre in number, but they are capable of rapid increase at the various temperatures employed and present a difficulty likely to be experienced, particularly in the management of low-temperature systems. After the plant has been in operation for a lengthy period, usually five hours or over, they have been found to be present to the extent of several millions per millilitre of milk. They can be spread by excessive periods of processing, by re-heating pasteurised milk and by " backwaters " in pipe-lines and plant which will assist such organisms to multiply rapidly. An accumulation of foam in the holding compartments, with consequent incomplete discharge of the vessels, will also assist their multiplication. Their presence in holding vessels causes the incoming milk to become inoculated, this contamination increasing in proportion to the length of time during which the plant is in operation.

Thermophilic bacteria were reported by laboratory workers so long ago as 1879, and at first were merely regarded as curiosities. They have become very troublesome in the routine commercial handling of milk, although they possess no public health significance as producers of disease. Their presence in the liquid is extremely undesirable as they cause spoilage of the product in addition to producing a high bacterial count as evidenced by the plate method of examination, and they emphasise the point that there are faults in plant design, operation and cleansing. Trouble from these organisms is not generally experienced if the duration of the plant's total run is less than five hours. Those distributors who are handling large quantities of milk often find it necessary to discontinue processing in order to cleanse all the internal surfaces of the apparatus on account of this danger. Indeed, treatment should be interrupted every three or four hours for cleansing purposes so that no difficulty is likely to be experienced. The presence of these organisms can only be controlled by careful plant management. As pasteurisation continues, they develop in the thin film of liquid which covers the internal surfaces of the equipment, multiplying rapidly. It is vitally necessary to ensure that all surfaces are kept free from any milk film or "milk-stone" for, as the milk passes through the apparatus, the organisms are distributed throughout the plant in ever-increasing numbers. Dead-ends, leaking regenerators and tanks which do not drain thoroughly should be eliminated, while the entrance of any condensed moisture from unsterilised surfaces into the liquid should also be prevented. The employment of air heaters placed above the milk surface in the holder compartments is a preventive measure generally employed in America, but not often found in this country. Pasteurised or partly-pasteurised milk should never be re-processed and the cloths employed in filtration of hot milk require to be frequently changed and used once only. Thermophilic growth is inhibited by the in-bottle and short-time processes which should be employed as a last resort if other attempts at control have failed. Some of these organisms are acid-formers so that an acid test alone is not a certain indication as to the necessity for closing down processing operations at any particular time. They are extremely susceptible to light, even weak daylight, and in excessive numbers may give rise to taints or to the clotting of the hot milk, although they do not multiply rapidly at room temperatures.

The *methylene-blue test* outlined on pp. 258 to 261, or the *resazurin test* (see pp. 253 to 255), may be employed for the detection of thermophilic organisms, if suitably modified as regards temperature. The milk with the added methylene-blue or resazurin solution is incubated at a temperature of 63° C. If the liquid is heavily contaminated with these bacteria, the dye will be reduced within three hours. They may also be detected if the *direct microscopic examination* is used. This test can be employed to denote their presence in "milk-stone" or milk film and will assist in checking the milk as it passes through the plant. Being elongated bacilli, they are readily identifiable. The *plate count* may also be employed to afford an estimation of the presence of these organisms if carried out at a temperature of 63° C., with milk immediately it has been processed.

The number of *thermoduric organisms* present is chiefly dependent upon the bacterial condition of the raw milk prior to treatment, and in this instance methods of production are intimately concerned. Anderson and Meanwell conducted certain experiments in order to discover the reasons for their presence in raw milk supplies and certain conclusions were reached. It was found that effective utensil sterilisation would reduce their numbers enormously, while wire gauze discs, which are often used for straining milk, were a frequent means of infection when improperly sterilised. Under ordinary farm conditions and without utensil sterilisation, more heat-resistant organisms are present in machine-produced milk than is the case when the animals are milked by hand. Further, any failure to cool the liquid immediately after production encourages this form of bacterial development. The policy of assembling milk in bulk in country creameries and its transport to the large centres of population for further treatment is favourable to the development of these organisms owing to the time factor involved. Many instances have been reported where the numbers of thermoduric bacteria present have been in excess of the maximum counts formerly permitted for pasteurised milk, immediately after both commercial and laboratory pasteurisation, where re-contamination after treatment was not a factor involved. There are a number of different types of thermoduric bacteria and normally they grow very slowly at room temperatures. In consequence, they have little influence on the souring of milk.

The following method for the examination of raw milk as a means of detecting the presence of these organisms may be employed. A standard loopful (0·01 ml.) of the sample to be examined is transferred to 4 ml. of melted nutrient agar (containing all the ingredients of standard agar except milk), at a temperature of 45° C., in a cotton-wool stoppered test-tube. The whole is mixed together and the tube placed in a slanting position so that the agar slope is about 3 inches long. Each tube is then incubated at 37° C. for 48 hours after which the colonies are counted. Counts obtained in this way from samples of milk examined before and after laboratory pasteurisation serve to detect those samples in which they are present.

The method of *laboratory pasteurisation*, suggested by Anderson and Meanwell, demonstrates whether or not milk so treated contains large numbers of organisms which are likely to resist the pasteurisation process. The examination is carried out in the following manner. Five millilitres of the sample are placed in a sterile test-tube, care being taken to ensure that none of the liquid touches the upper portion of the inside of the tube. A cotton-wool plug is inserted and the tube and its contents is incubated in a water-bath at a temperature of 63° to 65° C. for 30 minutes. The water level in the bath must be maintained at least 1 inch above the level of the milk in the tube. Following incubation, each tube is cooled to 10° C. in iced water and plate counts of the milk before and after incubation at 30° C. for 5 days are obtained in the usual manner. Comparison of the results of laboratory pasteurisation with those secured from milk obtained in the plant yields information as to the care and sterility of the equipment with which the milk comes into contact.

Churn-Rinsing Tests. These tests are now normal routine examinations carried out under the National Milk Testing and Advisory Scheme and are employed in order to check the efficiency of cleansing and sterilisation of churns at collecting stations and processing depots.

The bacteriological cleanliness of the containers following washing and sterilisation is related to the time which has elapsed after cleansing has taken place. The entire destruction of the organisms originally present is rarely achieved in commercial practice and those which survive the sterilisation process will multiply at varying rates according to the amount of moisture present in each churn and the temperature at which the vessel is stored. Ideally, the churns should be retained at a standard temperature, until they are tested but, as this is not possible in practice, they are examined within one hour of being cleansed, so that each container has had ample time to cool.

All churns which are to be tested should be first submitted to a visual examination and note should be made of their general condition. Dents in their internal surfaces, rusting, open seams and loose-fitting lids should be recorded as should the presence of any film, scale or milk solids. The wetness of the containers is important. A *dry* churn is one which exhibits no visible signs of moisture in its interior and is recorded as such, while one which has beads of moisture present is marked down as *moist*. Some churns will be found to contain pools of water and these require recording as *wet*. The amount of moisture present in any churn has considerable bearing upon the results likely to be obtained from the subsequent bacteriological examination.

Five hundred millilitres of sterile, quarter-strength Ringer solution is poured into the lid of the churn to be tested. This is washed with the liquid and replaced, the churn laid upon its side and rolled to complete twelve revolutions. After standing for five minutes, the rolling is repeated. Churns of the conical type should be held as near horizontal as possible when rotated, care being taken to ensure that their lips do not touch the ground The rinse is poured into a sterile container and is tested by means of the plate count. Rinse samples should be tested within six hours or stored at temperatures between 35° and 40° F. until the following morning. The number of colonies per churn is ascertained by multiplying the number present in 1 ml. of the rinse by 500, the results being classified as shown in Table 6.

TABLE 6

Colonies per Churn.	Classification.
Under 50,000	Satisfactory (S)
50,000 to 250,000	Fairly satisfactory (FS)
Over 250,000	Unsatisfactory (US)

If the interior of any churn is wet before the test is carried out, it is classified one grade lower than the colony count indicates. Churns for examination in this manner should be selected at random from each batch treated. If detergent and other factors are satisfactory, any unsatisfactory results obtained are probably due to the re-contamination of the containers after treatment, usually by the final rinsing water.

Davis and Watson have adapted the *resazurin test* for testing churn sterility. One millilitre of the rinse is introduced into 10 ml. of sterile, separated milk which is incubated at 22° C. for 24 hours. At the end of this period, the test is carried out at a temperature of 37° C. in the manner already described on p. 255. Any sample which gives a disc reading of 5 or less after 30 minutes' incubation should be regarded as unsatisfactory. Again it is important that the test should be carried out within six hours of the sample being obtained.

Bottle Sterility Test. It is important that clean empty bottles should be tested as a means of ascertaining the efficiency of the bottle-washing operations at the plant. Cold bottles only must be obtained for examination, 12 of these being selected at random from various crates; this will ensure a representative sample. They should be drained of any water which they may contain, and each should be sealed with a clean cap before being forwarded to the laboratory and packed in ice, if this is some distance away. Not more than six hours should elapse before the containers are examined.

Sterile, quarter-strength Ringer solution is employed, 20 ml. being added to each bottle of 1 pint or part of a pint size. Thirty millilitres of the solution are necessary when examining quart bottles. The container and its contents are well shaken and two 5-ml. quantities of the rinse water are plated, one plate being incubated at a temperature of 22° C. and the other at 37° C. for three days. The colonies are then counted and the bacterial content is calculated by multiplying this number by 4 in the case of pint bottles or by 6 when a quart bottle has been examined. The result is always expressed as "bacteria per pint bottle."

The following standards, set out in Table 7 below, are suggested as evidence of bottle sterility.

TABLE 7

Bacteria per pint bottle.	Classification.
Sterile to 200	Clean
200 to 500	Fairly clean
500 to 1,000	Dirty
2,000 to 5,000	Very dirty

In many cases it is usual to obtain some evidence of the presence of *Bacillus coli* in washed bottles and this test is carried out in the manner laid down for the plate examination for these organisms. Table 8 on p. 269 shows an alternative method of enumerating satisfactory results.

TABLE 8

	⅓ pt.	½ pt.	1 pt.	1 qt.
Bacteria per bottle less than	200	300	600	1,200
Bacillus coli per bottle less than	2	(Any size of bottle)		

Swab Tests. Although satisfactory for assessing the sterility of bottles and churns, rinsing tests are not suitable for dealing with large pieces of equipment, and for this reason swab tests are made. These are extremely useful for tracing specific sources of contamination. The technique of the test has been standardised by the Ministry of Agriculture and Fisheries and is carried out in the following manner. A measured area, usually 1 square foot, is swabbed with a sterile, gauze swab. This consists of 6 inches of unmedicated ribbon gauze which is wound round the lower end of a looped, 14-inch stainless steel wire to form a swab 2 inches in length. This is carried in a tube containing 25 ml. ¼-strength sterile Ringer solution. The test is then made in the manner outlined below. At least one square foot of surface area should always be examined if possible. The swab is removed from its container and is pressed against the side of the tube to remove all excess solution. It is then rubbed heavily over the area to be examined so that all parts of the allotted surface are treated twice, and it is important to ensure that all portions of the swab come into contact with the surface in question. The swab is then returned to its tube of solution. It is important that all samples should be examined within six hours after they have been obtained. If this is not possible, they should be stored at a temperature between 35° and 40° F. and dealt with on the following day.

When the swab has been returned to its tube, it should be twirled rapidly six times in the solution to mix the sample. It is then removed, the excess liquid being pressed out by pressure against the side of the tube. After mixing is completed, the sample is examined by means of the plate count at a temperature of 37° C. for 48 hours. The results are expressed as the colony count per square foot of surface. The standards specified are set out in Table 9 on p. 270.

TABLE 9

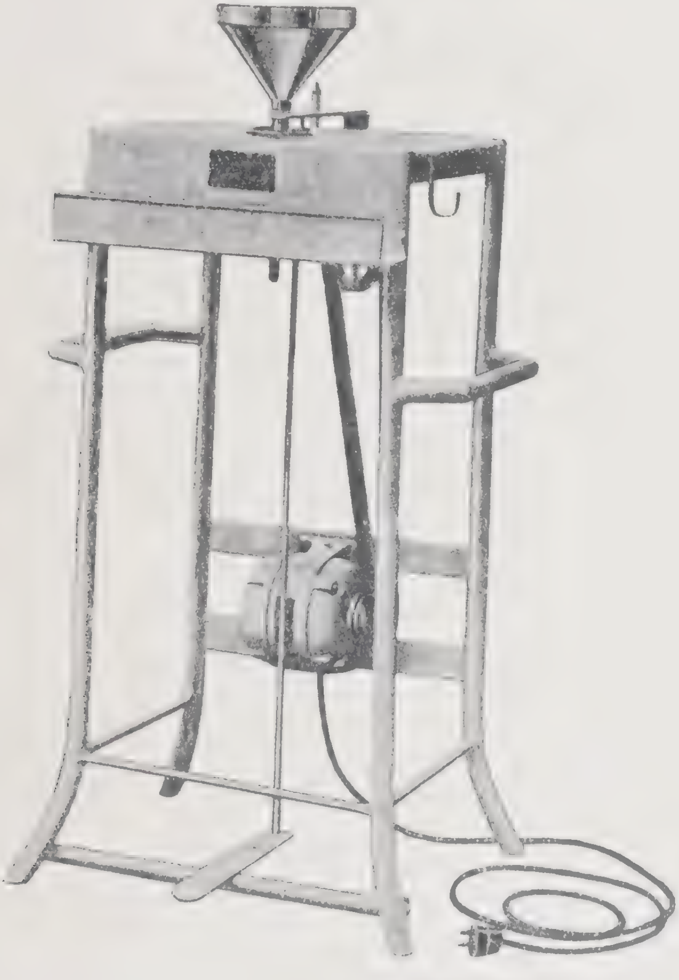
Colony count per square foot.	Classification.
Not more than 5,000	Satisfactory
5,000 to 25,000	Fairly satisfactory
Over 25,000	Unsatisfactory

The sterility of any large surface area should never be judged on the result of the examination of one swabbing, and for this reason several areas, each of 1 square foot, should be swabbed and tested at the same time.

Cell Counts. During the last few years, a method for the determination of efficient pasteurisation has been developed, based upon the condition of the cells contained in the heated milk. The liquid to be tested is mixed with methylene-blue stain and the mixture centrifuged. The stained cells are easily discovered under the microscope if a smear made upon a glass slide is examined. In milk which has been properly pasteurised, the cells are well stained, the compact masses of nuclei being darkly pigmented against a lighter background. In raw or improperly-pasteurised milks, the cells appear unstained and form clear areas against a darkly-coloured background.

Keeping Quality Test. This best affords a simple means of assessing the efficiency of treatment. The pasteurised milk is stored at a constant temperature of between 60° and 65° F., and it is tasted each morning and evening until a taint develops. In this way, its behaviour in the hands of the consumer is indicated and, when the test is applied to samples taken at various points in the plant, faulty methods of treatment may be readily discovered.

Sediment Test. This test is easily applied and is useful as a general check upon the milk entering the processing depot, providing as it does an object lesson to the careless producer and rendering assistance in determining the efficiency of the filtration or clarification methods at the farm. Where a large number of different supplies are received daily, the *Van Doorn Sediment Tester*, shown in Fig. 72, and designed for use on milk-receiving platforms, is a useful piece of apparatus. The liquid to be tested is automatically drawn from the container, measured into a glass cylinder to the required volume and automatically drained. Vacuum pumping is provided, the milk being passed through the filter card which can be dried and filed for future reference. Each test is completed in 10 seconds and the apparatus is easily cleansed.



By courtesy of Sutherland Thomson and Co.

FIG. 72. "Van Doorn" Sediment Tester (electrically driven).

Acidity Test. This test is based upon the assumption that all the acid produced in milk is lactic acid, and the percentage of acidity is calculated by using an alkaline solution of known strength to neutralise the lactic acid in a given quantity of milk. If milk is stored at ordinary temperatures, acidity gradually develops owing to the multiplication of the lactic-acid organisms

which it contains. A point is finally reached when this acidity is
sufficient to curdle milk owing to the precipitation of its casein
Phenolphthalein, which is colourless in acid solutions and becomes
red in the presence of an alkali, is used as the indicator. Te
millilitres of the milk to be tested are placed in a dish and 1 ml
of the indicator is added. A standard solution of deci-norma
caustic soda is run into the mixture from a burette. The additio
of this liquid to the milk is carried out slowly and carefully
drop by drop, the mixture being continually stirred until th
pink colour caused by the indicator persists for 5 seconds
The liquid is then neutral in reaction. The readings of th
burette before and after the caustic-soda has been adde
give the amount of solution required to obtain the necessary
reaction. Each millilitre of alkali used is taken to denot
1° or 0·1 per cent. of acidity. Thus, if milk needs 1·5 ml. of alkal
to obtain the neutralisation of the acid, the liquid would posses
an acidity of 1·5° or 0·15 per cent. The standard limit of acidit
usually recognised is 2° or 0·2 per cent. From a bacteriologica
standpoint the test is crude although some relationship undoubtedly
exists between the degree of acidity and the numbe
of bacteria in the liquid. This examination possesses the dua
advantages of convenience and rapidity of use.

Specific Gravity. Average milk possesses a specific gravity o
1·035, but this may vary between 1·027 and 1·039. Within thes
limits, estimation of specific gravity supplies a rough indicatio
as to the composition of the milk tested. While the specifi
gravity of a sample may be obtained in a variety of ways, th
lactometer is usually employed for this purpose. It possesse
certain advantages if used in conjunction with the Gerber tes
for fat percentage (see p. 274). The lactometer is a glass instru
ment with a weighted bulb and stem, a scale being marked upo
the latter portion of the instrument. It is actually a hydromete
suitably scaled, and operates on a similar principle, *i.e.*, the la
of displacement. The scale is marked from 0 downwards to eithe
40 or 50, the 0 representing 1,000, which is the specific gravity o
pure distilled water at 60° F. Milk is heavier than water and th
better its quality the heavier it should be. To obtain its specif
gravity, a cylindrical jar is filled with milk to within 2 inches o
the brim and the instrument is allowed to fall slowly into th
liquid. The lactometer is immersed to the mark 0 by means o

a slight pressure of the finger, after which it is allowed to rise and settle at will. The jar should be slightly wider and deeper than the instrument. After immersion in the manner described, the instrument will remain stationary and, at a point where the stem clears the surface of the liquid, the milk will cling around it. It is customary to allow for the rise of milk by capillary attraction at this point, the usual allowance being ½°. If the lowest figure clearly shown on the scale is 31°, the accurate reading after correction would be 31·5°. The average specific gravity of milk is calculated at a temperature of 60° F. Therefore, if the temperature is above or below this level, the reading will be affected. The temperature of the milk under test must first be ascertained by means of a thermometer well stirred in the liquid. It will be found in practice that a milk temperature of exactly 60° F. is rarely found, and it is therefore necessary to make a correction in the reading. It is usual to allow 1° of specific gravity for every 5° F. deviation in temperature from 60° F. If the temperature is above this figure, the allowance should be added to the actual reading, while if below, the allowance is deducted.

Milk which is richer in fat in comparison to normal milk gives a lower lactometer reading, while those milks which are richer in non-fatty solids show correspondingly higher results. Milk which is frothing will give an untrue figure as the presence of air bubbles leads to artificial lightness. It is also essential that the liquid should be well stirred before the specific gravity is obtained. Lactometers of good quality should always be employed, cheap apparatus being unreliable. The instrument should invariably be maintained in clean condition and should be tested occasionally with pure distilled water at a temperature of 60° F.

The *Richmond Scale* is employed in connection with the lactometer, the formula used being :—

$$T = 0{\cdot}25G + 1{\cdot}2F + 0{\cdot}14$$

where T = Percentage of total solids
G = Lactometer reading in degrees (corrected to 60° F.)
F = Percentage of butter-fat

The percentage of non-fatty solids present is readily calculated from this formula. The modern form of Richmond scale indicates the temperature correction of the specific gravity of milk and the total solids corresponding to known lactometer and fat values. The scale is sufficiently accurate for all ordinary purposes and is employed in connection with the Gerber test for fat percentage. On the scale, the fat is graded from 0·1 to 6 per cent., the divisions being clearly marked, and this percentage may be calculated to two decimal places. A small scale on the inset slide rule adjusts itself to a temperature scale on the main piece, and correction of the apparent lactometer reading with the temperature can be exactly made. If the sliding portion is set to the known figure, the result is immediately and plainly visible.

Fat Percentage Estimation. The determination of the percentage of butter-fat contained in a given sample of milk is one of the most important chemical tests, the *Gerber* method, which has been standardised and is now extremely simple to carry out, being usually employed for this purpose. It is a cheap and speedy method and affords both the responsible official and the processing depot a ready means of estimating the qualities of the various milk supplies received at the plant. By the action of centrifugal force, it is possible to separate compound fluids and to estimate their various constituents. The Gerber method renders such separation more complete, casein in suspension being dissolved by the sulphuric acid used, while the fat is clarified by amyl alcohol. The alcohol also assists the fat to pass more easily through the aqueous milk serum by reducing surfac tension. There are many Gerber machines to be obtained some driven by mechanical means, usually steam or electricity while the smaller types are generally hand driven. When steam is available, steam-driven apparatus is sometimes preferred to those motivated by electricity as a suitable temperature may be maintained in the centrifuge bowl. Their principle of operation is a quick rotary movement by a system o geared wheels. The special Gerber tube is used and this is fitte with a rubber stopper. Eleven millilitres of the milk to be teste are added to the tube, followed by 1 ml. of amyl alcohol and 10 ml of sulphuric acid (Spec. Grav. 1·82). Extreme care is essentia when the acid is added, the tube being sloped to receive it and th substance will settle below the milk layer. The tube is then tightl stoppered and the number of the sample recorded upon it, afte which it is wrapped in a duster and well shaken. After thi operation has been completed, it will be noted that the precipitated casein is completely dissolved, leaving a dark-coloured liquid. The tube, balanced by others, is placed in the centrifuge with the stoppered extremity towards the circumference of the apparatus, pockets being provided to hold the various tubes. The lid is screwed down and the machine spun rapidly for two minutes. The tubes are then removed and each is held with the graduated end upwards. By manipulating the rubber stopper, the fat layer in each tube is brought within the range of the graduations marked upon the stem when the fat percentage may be read off directly. To correct for temperature, the tubes should be placed in a water-bath at 65° C. for three minutes before the reading is taken. If a fluffy layer appears at the base of the fat column, the test should be repeated, care being taken to see that the rubber stopper is satisfactory. Other reasons for this phenomenon are insufficient centrifuging or the addition of amyl alcohol may have been overlooked.

Phosphatase Test. In the past, the only method by which it has been possible to ensure that milk has been retained during processing at the requisite temperature levels for the prescribed periods, has been to submit the product to frequent bacteriological examinations and to combine this procedure with inspection of the plant and the methods employed. While such inspections are still essential and must be carried out at frequent intervals if they are to be of any value, in themselves they afford no conclusive evidence that correct operation is constantly maintained. It cannot be denied that the experienced person, by inspection, may be able to satisfy himself to some extent that sources of trouble in the plant are being avoided and an efficient inspection will be of assistance in deciding whether or not the apparatus is functioning in a satisfactory manner. As might readily be understood, this procedure is likely to occupy a considerable portion of the controlling official's time, if carried out with the necessary frequency and thoroughness, and the need for a quicker, more certain and efficient method of estimating the accuracy of processing became urgent.

Another important point which requires to be considered is the fact that a considerable quantity of pasteurised milk may be sold in one area which has been processed in an adjoining district and the responsible official has therefore found himself unable, in many instances, to inspect either the plant or the methods employed. Even when inspection shows that the apparatus is operating apparently in an efficient manner, slight errors can arise which may be difficult to discover by visual examination alone. While in the past reliance has had to be placed upon bacteriological control, and although such tests may still be required in connection with processing methods, it must be remembered that they are liable to considerable sources of error on account of weather conditions, time between treatment and sampling and individual faults in technique which may arise when such examinations are made. For these reasons, many tests based upon the effects of heat on the cellular content, and on the physical or chemical properties of milk, have been the subject of prolonged experiment, but with the exception of the phosphatase test, originated by Kay and Graham, none were found to be entirely reliable as indicators of improper processing methods. It must be obvious, therefore, that no one interested in the control of heat-treatment or pasteurisation methods can fail to welcome the advent of this test which provides the best solution to the difficulties experienced in the efficient control of processing. This test has brought about a complete revolution in the methods employed for controlling the efficiency of heat-treatment, as it is now possible from the laboratory examination of samples to determine whether or not such treatment is efficient, revealing faults which were unsuspected following inspection, and resulting in a steady increase in the efficiency level of many processing plants. No other test can supply the same or comparable information.

The test makes use of colorimetric methods and depends for its success upon the fact that the enzyme, *phosphatase*, which is a constant constituent of raw milk, is completely destroyed by processing within the specified time and temperature limits prescribed for either the low-temperature or short-time systems. The presence of this enzyme is readily detected and its presence in a sample of milk following heat-treatment provides evidence that the liquid has not been satisfactorily processed. If the required temperature has not been attained, or if such temperature has not been maintained for the requisite period, the enzyme survives to a greater or lesser degree. From the public health point of view it is important that all pathogenic organisms should be destroyed at a lower temperature than that employed in processing or after slightly shorter periods of exposure. Apart from guinea-pig inoculation, therefore, a negative phosphatase test is the best guarantee readily available at the present time that a sample of heat-treated or pasteurised milk is free from tubercular organisms while, when the thermal death-points of other pathogenic bacteria are considered (see p. 30), it proves its freedom from organisms likely to be injurious to the health of the consumer, always excepting any re-contamination after treatment. On the other hand, a positive result shows that processing has erred as regards either time or temperature, or that through some fault in either plant or treatment, raw milk has been allowed to mix with the processed product, an admixture of 0·15 per cent. or more of such milk being readily detectable. The fact that agitation has not been employed in an effort to bring about an apparent increase in the cream-line and that there has been uncontrolled or excessive foaming, with a consequent low foam temperature, can also be demonstrated. Among the grosser errors which may be discovered are carelessness in operation or the deliberate omission of the holding period, fluctuations in temperature due to manual control and poor or defective equipment. It will rarely be found that the operator is either deliberately under-processing his product or wilfully adding raw milk to the finished article. If such cases are discovered, the offender's licence should be cancelled and a prosecution should certainly follow. Usually, faults in processing, particularly in the case of up-to-date machinery, are due either to an unexpected breakdown of some portion of the plant or to carelessness or unreliability on the part of an employee.

The following *apparatus* is required for making the test :—

(1) A Lovibond Comparator, as shown in Fig. 73. This apparatus possesses two 25 mm. glass cells and has a disc which is fitted with four blue-coloured standard glasses which contain 0·5, 1·5, 2·3 and 6·0 Lovibond units of blue respectively. A wooden block is provided to fit inside the apparatus and firmly hold the cells. If desired, the Lovibond All-purpose Comparator as described for use with the resazurin test (page 252) and shown in Fig. 70, may be employed.

(2) An incubator or water-bath, thermostatically controlled at 37 ± 0·5° C.

(3) A pipette to deliver 4·5 ml., preferably of dark glass.

(4) A number of 0·5 ml. straight-sided pipettes, the mouth-pieces of which should be plugged with cotton-wool. One pipette of this type is required for each sample examined.

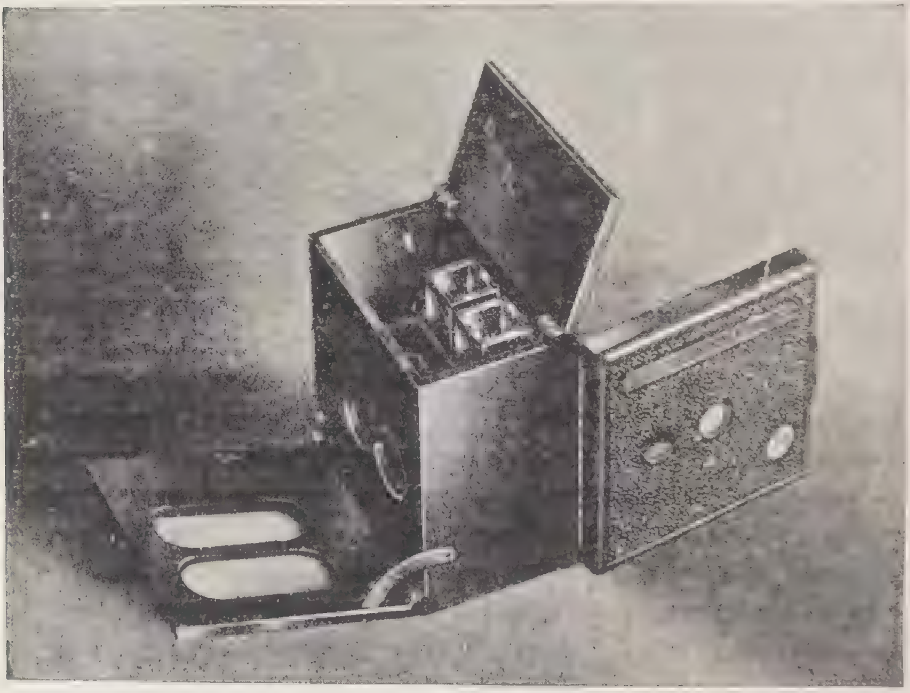
(5) A pipette to deliver 2 ml.

(6) Test-tubes etched at the 10-ml. level, provided with phenol-free rubber stoppers. One tube is required for each sample to be tested. Before use, they should be cleansed with chromic acid.

(7) Filter funnels and stands, together with a supply of Whatman No. 40 filter papers.

The following *reagents* are also necessary :—

(*a*) *Buffer-Substrate Solution.* This contains 1·09 grams disodium phenyl-phosphate buffered with 11·45 grams sodium diethyl barbiturate and made up to 1 litre with distilled water. This solution should be saturated with chloroform and will remain stable for 48 hours if stored in a refrigerator. If it has been kept for longer periods, it should be tested before use. It is usually more convenient to employ standardised tablets for the production of this solution, one tablet being dissolved in 50 ml. of distilled water and the solution saturated with chloroform.



By courtesy of the Tintometer, Ltd.

FIG. 73. Lovibond Comparator (used for Phosphatase Test).

(*b*) *Folin and Ciocalteu's Phenol Reagent.* This must be diluted with twice its volume of 5 per cent. (weight per volume) sodium hexametaphosphate solution before use. This mixture must be carefully protected from dust or from any reducing substance.

(c) *Sodium Carbonate Solution.* A 14 per cent. solution (weight per volume) of pure anhydrous sodium carbonate which should have been standardised by titration.

Certain important *precautions* require to be observed in making the test. The apparatus and test reagents must be rigidly standardised and obtained only from an approved source. They must be stored at a safe distance from phenols or articles containing such substances, and it should be borne in mind that difficulties in testing have been experienced through the use of impure chemicals. It is important that all reagents should be stored in a cool, dark place and protected from dust, while glass bottle stoppers and caps should be used for their protection. All rubber stoppers require to be tested for phenolic impurities before they are used and glassware must be carefully washed in chromic acid, experience having proved that new glass may carry enough phenol to produce a blue tint and so affect the test. Saliva contains phosphatase and contamination of the pipettes must be avoided. No testing should be carried out in direct sunlight while only freshly-boiled, distilled water should be used for dilution purposes.

The *technique* of the test now required to be carried out on all heat-treated or pasteurised milk, is set out in the Addendum to Memo 139/Foods of the Ministry of Health. Samples kept at room temperature should be examined within 18 hours of processing in every case, although if this is not possible, they may be stored in a refrigerator until examination is convenient. All tests should be carried out in duplicate. Ten millilitres of the buffer-substrate solution are run into each of two test-tubes graduated at the 10-ml. mark and to each tube is added 0·5 ml. of the well-mixed sample. A thorough shaking of the sample under test is important as the major portion of the phosphatase appears to be associated with the fat globules. Three drops of chloroform are added to each of the tubes and these are immediately sealed with sterile rubber stoppers, the contents well mixed and incubated either in a water-bath or incubator at a temperature of 37 ± 0·5° C. for 24 hours. At the expiration of this period they are removed from the bath, cooled, 4·5 ml. of Folin's reagent solution added to each and they are then allowed to stand for three minutes. At the expiration of this period, their contents are filtered into fresh tubes, and 2 ml. of the 14 per cent.

solution of sodium carbonate are added to each tube containing 10 ml. of the filtrate, the whole being well mixed. The tubes and their contents are placed in water which is kept continuously boiling, where they remain for two minutes. The mixture is cooled and transferred to the right-hand comparator cell, a blank containing distilled water being placed in the left-hand aperture.

The comparator is placed so that it faces a good source of daylight—north light if this is possible, direct sunlight being avoided, and the colour disc is rotated until a reading is obtained. The results are returned as shown in Table 10.

TABLE 10

Units of Blue.	Results described as:
Below 2·3 units	Negative phosphatase test
2·3 to 6·0 units	Insufficiently heat-treated
Above 6·0 units	Grossly under-treated

Raw milk usually gives a reading of over 30 units of blue, therefore a reading above 2·3 units may indicate either incorrect treatment or the addition of raw milk. No differentiation between the probable causes is possible on the results obtained.

The remainder of the milk which is being tested should be stored in a refrigerator until the incubation period of the samples under test is completed when *control tests* should be carried out on fresh portions of milk from those samples which give a reading of above 2·3 units of blue. In these tests, 10 ml. of buffer-substrate solution are mixed with 4·5 ml. of the test reagent, 0·5 ml. of milk being added and the whole well shaken. This mixture is allowed to stand for three minutes and is then filtered into a graduated test-tube after which 2 ml. of sodium carbonate solution are added to 10 ml. of the filtrate. The contents of the tube are well mixed, following which the tube is placed in boiling water for two minutes. The mixture is cooled, filtered if necessary, transferred to the comparator cell and the disc read. The colour of the liquid should not exceed 1·5 units of blue. If a higher reading is shown, the presence of phenolic impurities is indicated. These would not be in evidence if the milk had been correctly processed or if it was uncontaminated, and the reading may therefore indicate either faulty reagents or technique. If two or more samples examined at the same time show a control reading above 1·5 units of blue, it may be assumed that either the reagents or the technique are at fault.

It should be noted here that reports received from the United States of America suggest that certain heat-resistant organisms found in milk are capable of producing a type of phosphatase which may affect the result of the test, although it is emphasised that the enzyme produced differs considerably from that normally present in milk. This point, however, must necessarily be borne in mind.

A *test of reagents* is of considerable importance and is carried out by incubating a tube containing buffer-substrate solution and chloroform but without milk with each batch of samples, the test being completed in the usual manner. When measured in the comparator, the resultant colour should not exceed 0·5 Lovibond units of blue.

The *advantages* to be derived from the test are its applicability to small samples of milk and the fact that it is reasonably simple and cheap. Errors in experiment are comparatively negligible, it is capable of detecting small mistakes in processing, and on account of the temperature at which the enzyme phosphatase is destroyed, it bears a known relationship to the thermal death rate of pathogenic organisms.

The test possesses certain *limitations* in that it can only detect the addition of 0·15 per cent. or more of raw milk. Further, as regards the short-time process, it is only possible to detect a temperature drop of 3° F. or a holding time of less than 6 to 10 seconds. It cannot be used for the testing of sour milk, and 24 hours must elapse before any result is obtained. Ability to obtain a quicker result would be of considerable value, and it is understood that due to the efforts of Aschaffenburg and Neave, it is likely that a quick routine test will materialise in the near future.

The following list shows errors or defects in treatment which have been revealed by the test. The errors indicated can readily be assessed either as major or minor faults, but the actual cause of failure to pass the test can only be ascertained by inspection of the plant during processing and sampling the milk during the actual run for checking purposes.

(1) *Inadequate Holding Period.*
  (*a*) Leaking outlet valves.
  (*b*) Deliberate shortening of holding period.
  (*c*) Fast recording thermometers.
  (*d*) Wrongly connected or faulty valves in multiple-compartment plant.

(2) *Low Temperatures indicated by the Recorder.*
  (*a*) Compartments only partially filled with milk and not maintaining temperature.
  (*b*) Cold compartments at commencement of processing.
  (*c*) Draughts from doors and windows affecting the holder.
  (*d*) Poor or faulty insulation of holder compartments.
  (*e*) Faulty agitation allowing a cool layer of milk to remain at the base of the holder compartments.
  (*f*) Steam-raising boiler for plant of insufficient size. When sterilisation of bottles was in progress at the same time as processing, the boiler was unable to cope with the extra output of steam demanded and the temperature of the heating medium fell considerably.
  (*g*) Poor control of temperature of heating water.
  (*h*) Heating at too low temperature.

(3) *Low Temperatures not shown on Recorder.*
  (*a*) Thermometer bulb passing through heated jacket.
  (*b*) Improperly pasteurised foam containing last-drawn milk from holder compartments.
  (*c*) Thermometer bulbs touching metal lining of vat.
  (*d*) Breakdown of recorder.
  (*e*) "Cold pockets."
  (*f*) Failure to test thermometers at frequent intervals.

(4) *Added Raw Milk.*
  (*a*) Defective or improperly-closing valves.
  (*b*) Leaking regenerators.
  (*c*) Milk passing over surfaces previously used for handling raw milk.

The test is one which gives the operator and the controlling official detailed information regarding laxity in plant management which could be obtained in no other manner. Pasteurised milk no longer depends upon the consumers' confidence for its reception as a safe milk. It is now possible to prove whether or not this is so. In the past, it is quite certain that much milk sold under the designation "Pasteurised" has been insufficiently processed, particularly as many plant operators attach too great an importance to cream-line and accordingly may either slightly reduce the temperature or the period of heating with this end in view. From the standpoint of milk supervision, the important contribution this test makes is that the heat-treatment given to milk can now be accurately determined from the milk itself at any point after it has been processed. This is the contribution of the test, and it is one which all those responsible for the control of processing must sincerely welcome.

Daily samples should be obtained from each plant producing either pasteurised or heat-treated milks and it would be advisable if formal weekly samples for submission to this test were collected from roundsmen under the provisions of the Food and Drugs Act, 1938, so that prosecutions could be instituted in the case of any milk found to be improperly pasteurised. It should be emphasised that unsatisfactory results need to be quickly followed up, and it will be found that plant operators generally are appreciative of any constructive advice which may be tendered. On the other hand, it is suggested that the failure of any milk to comply with the test on three successive occasions should be regarded as sufficient grounds for the withdrawal of the operator's licence to produce or retail milk of this grade.

Office Records. Office records and the notification of the results of any examinations of samples to producers of heat-treated and pasteurised milks are of some importance. The immediate recording of the necessary particulars is essential and a complete record of every sample from each separate supply entering the district should be kept. A card designed for this purpose will be found useful both for the owner of the plant and the controlling official. These cards should be filed alphabetically so that they are available for easy reference.

A suitable form for the notification of the results of any examinations is also essential. As coliform examinations are not specified by any legal enactment for these classes of milks, the results of such examinations, if carried out, should be detailed under the heading "Remarks." Both the record card and the form of notification should be designed so that they may be readily amended if desired.

CHAPTER XIV

FUTURE DEVELOPMENTS

The various aspects of pasteurisation and other methods of milk processing having been discussed, it now only remains to consider briefly the future trends in milk treatment and to make suggestions for the distribution of a safe milk to the entire population of these islands.

There is no doubt that pasteurisation and other forms of heat-treatment have come to stay; at least, for some considerable time. Granted, at some future date, it may be possible to provide every inhabitant of Great Britain with raw, disease-free milk, but that time is still far distant. To attain this end, the complete eradication of all diseases from the dairy herds of this country is a first essential. Steps are being, and will continue to be, taken by the veterinary profession to achieve this ideal state of affairs, but the difficulties with which they are confronted are enormous, and it is likely to be very many years before public health authorities are able to give their blessing to the universal consumption of milk in its natural, raw state.

In view of the position at the present time, it will be seen that some form of heat-treatment, and preferably pasteurisation, will be essential for many years to come. For this reason, it would appear to be a most urgent necessity that the White Paper proposals (Cmd. 6454) and Defence Regulation 55G should be implemented without any further delay. No public health authority can view the present position with equanimity and, in spite of criticisms so often voiced with little knowledge of the true principles of milk treatment, pressure should immediately be brought to bear upon the authorities concerned, by the medical profession in conjunction with public health bodies, in order to secure the immediate heat-treatment of the country's milk supply, particularly in the larger centres of population.

Improvements in milk processing, as carried out at the present time, are necessary in order to achieve this desired state of affairs. The larger distributors with their adequate, fully-trained technical staffs are generally above suspicion. When compulsory pasteurisation comes, as it most certainly will in the not too distant future, it is essential that *all* distributors should be equally efficient in both knowledge and methods. At the present time, it is generally the smaller dairymen who lack both the financial means and the technical knowledge to pasteurise milk in an efficient manner and, what is probably more important, they do not possess a sufficient understanding of the methods required to suitably control processing. The efficient treatment of milk will be essential when pasteurisation becomes compulsory and this end is impossible of attainment unless some radical alterations take place in the present system.

In order to obtain the desired efficiency, it would appear that two alternative avenues of approach to the problem exist. The first of these is that all milk should be pasteurised in the plants of the large distributors or in additional creameries to be established by the Milk Marketing Board from which the smaller retailers might purchase their supplies in bulk for subsequent bottling, or preferably, already bottled for delivery. Heat-treatment is a scientific process and is one which cannot be carried out successfully unless adequate plant is provided, and unless this is supervised by trained personnel. The alternative would appear to be for producers in our various urban areas to combine co-operatively in order to process their milk in suitable premises with modern plant, and supervised by capable staffs who could be employed by such amalgamations. The main requirements for success are suitable modern plant and methods and it is only by a radical re-organisation of the whole distributing industry that any progress, in this direction, is likely to be achieved. It may be thought that these suggestions are rather extreme in their scope, but it should never be forgotten that public health is at stake and neither laxity nor the wishes of vested interests should be allowed to interfere with the production and distribution of a safe milk.

The past few years have seen the rapid development of the high-temperature, short-time process while that older but well tried method of low-temperature treatment has been relegated into the background. It has been conclusively proved that the high-temperature system can be operated successfully, but it is doubtful if this is really the case in many instances. The low-temperature system was safe, providing as it did an adequate safety margin. This latitude is not available when the short-time process is employed and it therefore behoves all operators to pay particular attention to this lack of margin in what is really a new and, as yet, a comparatively untried system. Whatever method is employed, the weakest spot, and the one which is most difficult to overcome, is post-pasteurisation contamination, either from the plant itself or from bottles and other containers. This serious difficulty could be avoided by in-bottle treatment, a method which is, without any doubt, the ideal system of milk processing, although, no doubt, it possesses certain financial disadvantages. As regards this method, it should be noted that, in view of the favour with which the short-time process is viewed by the trade, a method which it must be agreed is extremely economical both in labour and materials, it is to be hoped that the present experiments being undertaken in adapting short-time pasteurisation to in-the-bottle processing will soon be successful and that the near future will see this system introduced as a commercial proposition and one which will be more acceptable to milk distributors than it appears to be in its present form.

The emphasis which has been placed upon in-bottle processing in the preceding paragraph must not, however, be allowed to cloud the outlook as regards future developments in methods of treatment. During the last few years, and in many other countries but ours, various methods of attaining the desired end have been developed and used commercially. Stassanisation is one of these systems which would appear to have bright prospects if suitably modified, while pasteurisation by means of electricity has also been employed in the United States of America with considerable success. It is difficult to understand why attempts have not been made to use these processes on a commercial scale in this country. There are several other methods of treatment available, any one of which might be successfully employed, perhaps with some slight modification, for the purpose in view. It may be that certain difficulties exist in operating such processes on a commercial scale, but it would appear that our larger distributing firms could usefully experiment with other methods of heat-treatment and could perhaps eventually employ them in the everyday processing of milk. Vacuum pasteurisation has also been used commercially both in the Dominions and in the United States of America. Here again is a method which might be given a trial in this country. A further method of treatment which could surely be developed is the artificial irradiation of milk. This process, properly carried out, will destroy both non-pathogenic and pathogenic organisms in the liquid and, as employed in the United States of America and particularly in Germany during the war, it can also be used to pasteurise cold milk, thus solving the dual problems of safety and nutritional improvement at the same time. Irradiated milk has never made the headway in this country which it deserves, and it would appear that there is ample scope for advancement in this direction. It must be admitted that the War which has just ended has retarded advancement to a certain extent, but is it not a fact that the people of these islands are either extremely conservative in their outlook or too bound up with tradition to experiment with new methods?

In the preceding chapters, stress has been laid continually upon the necessity for the expert control and supervision of milk processing. The scientific problems involved render it essential that all supervisory staffs should be properly trained in methods of control. Prior to the war, this was being achieved to some extent by many large distributors who operated their own training schools for this purpose. While this procedure was entirely admirable, danger was likely to arise owing to the method of teaching employed which might tend to be too conservative, and the students were likely to suffer from a lack of new ideas. Granted, several technical colleges provided courses in milk processing, but these were insufficient to cover the whole country. Here again is a field for development and one in which education authorities might play a more useful part. The introduction of compulsory pasteurisation at some future date will necessitate adequate trained personnel and a rapid expansion in educational facilities is essential at the present time to meet this need. A similar need exists with regard to statutory supervision. Thoroughly trained inspectors will be required to supervise processing plants and the persons responsible for this work should certainly undergo suitable technical training in order that they may be fully conversant with the principles involved. The advent of compulsory heat-treatment will require the supervision of many more plants throughout the country, and the opinion has been expressed by various high authorities that specially trained officials will be needed for this purpose. This suggestion is worthy of serious consideration by the controlling authorities, and intensive courses of training should be organised forthwith for those whose duty it will be to supervise the production and distribution of pasteurised milk.

Finally, no method of milk treatment can operate without some form of legislative control. The present legal enactments are extremely chaotic, and there is no doubt that, in the near future, the Minister of Health will take the necessary steps to improve matters in this direction. Rumours are already prevalent and at least one authoritative statement has been made that new Regulations for the compulsory heat treatment of milk in urban areas will be soon forthcoming, and it is to be hoped that when they do appear, these will be simple in drafting and clear in intention and that they will not only cover processing and the correct application of time and temperature but will also deal with the methods of distribution to be practised and provide for adequate bacteriological control of the treated product. In addition, it should be a requirement that all plants should be certified by the licensing authority as being of approved design, and no alterations or additions should be allowed to be made to any plant without the sanction of the controlling officials. Operators and their foremen should be certificated as being qualified to supervise the methods of processing employed.

At the present time, pasteurisation is an essential method of milk treatment and it therefore behoves all interested in this method to advance with the times, making use of all scientific developments as they appear and providing the necessary technically-trained staffs who are necessary for control and supervision. Only in this way can the process be commercially successful and above suspicion from the public health point of view.

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